NEW EDITION

You and Science

SCIENCE FOR BETTER LIVING

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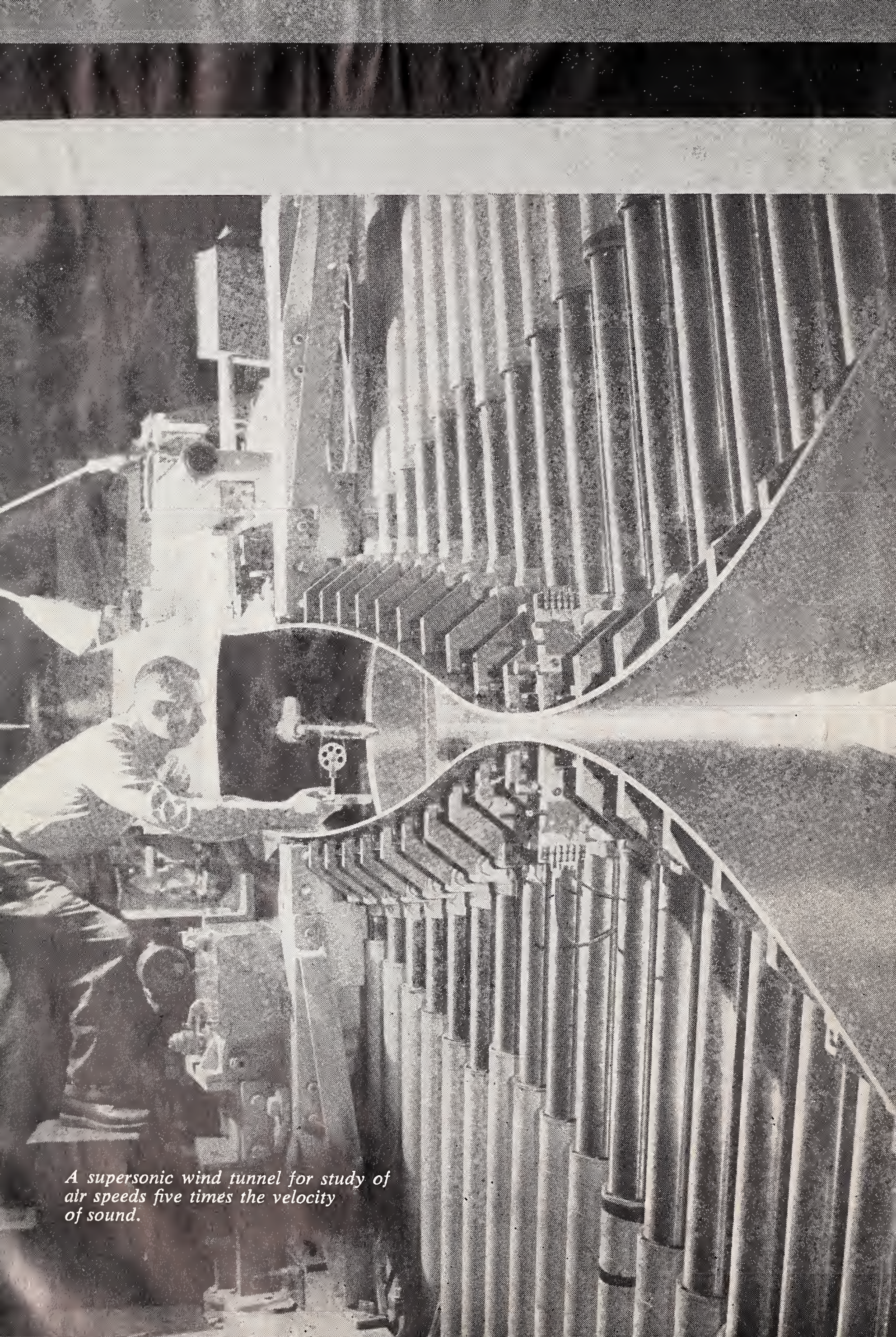

A supersonic wind tunnel for study of air speeds five times the velocity of sound.

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HARCOURT, BRACE & WORLD, INC. NEW YORK CHICAGO ATLANTA DALLAS BURLINGAME

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FRONT COVER PHOTO: *This is one type of three-stage rocket used in attempts to reach the vicinity of the moon. The picture shows the gantry with the vehicle ready to take off.* (*Official U.S. Air Force Photo*)
BACK COVER PHOTO: *The face of the southern portion of the moon at last quarter as viewed through a telescope.* (*Mt. Wilson and Palomar Observatories*)

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PRINTED IN THE UNITED STATES OF AMERICA

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UNIT 1

Man—As Scientist

As you know, scientists do many interesting things. They shoot rockets into space, explode atoms to release their energy, study the motion of stars through telescopes and the life cycle of microbes through microscopes. You, too, some day may do things like these.

Here is Dr. Walter L. Hermann of Yale University, a scientist whose concern is to discover a better treatment for cancer, one of the dread killers of our times. In his research he uses the tools of the scientist, he talks and works closely with other scientists, he reads for long hours, he does and supervises many experiments — and then, the evidence permitting, he draws conclusions and sets new problems which may uncover patterns in the progress of cancer in the body, and — possibly — may uncover the causes of cancer and lead to its cure. Like all scientists he spends most of his time in thinking. This is the way of the scientist — to do his best with his brain to find ways to improve life on this planet Earth.

Your Science Inventory

If you can answer all of the following questions, you are doing very well for your age. Don't be discouraged if you can't answer them. You should do much better after you study this unit, and better still after this year with *You and Science.*

1 An animal whose cerebrum had been injured would be most likely to lose its ability to (a) breathe, (b) kick, (c) live, (d) remember.

2 The following are all steps in good study habits, except: (a) defining your task, (b) getting materials together, (c) music on the radio, (d) setting up a plan.

3 Traits that only man has include (a) five fingers and a large brain, (b) a flexible thumb and ability to speak, (c) two legs and vocal cords, (d) a thumb and a brain.

4 Which one of the following statements about science is most nearly true? (a) A scientist repeats all the important experiments about which he reads. (b) There is only one scientific method. (c) Generally speaking, science means doing one's best with one's brain. (d) Once a fact has been accepted by great scientists it is unnecessary to investigate it again.

5 A hypothesis is (a) an established theory, (b) a guess, (c) an observation of facts, (d) a controlled experiment.

6 The largest part of your brain is the (a) cerebellum, (b) cerebrum, (c) medulla, (d) pituitary.

7 By his experiments with maggots (which develop into flies) the scientist Redi (a) proved that all living things must have parents, (b) proved that insects must come from other insects, (c) did not prove, but made it seem very likely, that all insects came from other insects, (d) did work of no value, except as regards the kind of flies he studied.

8 An action which is *not* a reflex act is (a) blinking, (b) heartbeat, (c) jumping at a sudden noise, (d) writing a story.

9 A dog's mouth waters when he hears a bell. This is a (a) conditioned reflex, (b) habit, (c) instinct, (d) simple reflex.

10 Scientists have determined the speed of light to be a (a) constant, (b) light-year, (c) standard unit, (d) variable.

CHAPTER 1

Ways of the Scientist

Science means doing your best with your brains, no holds barred. Science isn't magic. It is men at work — in the laboratory and library. It is men asking questions and finding answers in many ways.

AIRMAN DONALD G. FARRELL, 23 years old, was in his 3 × 5 foot cabin . . . sealed off from earth. For a week he lived in his own private surroundings, breathing air at half the pressure on the earth, sleeping a few hours at a time, operating his instruments in order to keep the "ship" on course. He also had problems to do in order to keep himself alert in his cramped space. Sometimes he had to bring two lights together on his dashboard; sometimes he had to "fly" a certain course; sometimes he worked puzzles; sometimes mathematical problems. And he did live under these conditions for seven days.

But Airman Farrell knew he was on the ground. He had been spared the rocket take-off and its dangerous crushing pressure. He had been spared the strange weightlessness he might experience in outer space. He was, after all, part of a scientific experiment — an attempt to answer the question: What qualities should the ideal space man have? He was submitting himself to one of the scientist's ways of discovery. And he was using many sensitive tools of measurement.

Can you see that he, too, was in one way himself a tool of measurement and discovery?

How would you go about studying *on earth* conditions which are *not to be found on earth?* How do scientists find out what man will meet in space before they actually send a man out into it? This is a problem for scientists and engineers. And how scientists tackle problems like this and others is what this chapter and this entire book is about.

This chapter is also about: How small is small — the size of an atom, for one example, and the weight of an electron, for another. It is also about how large is large — the size of the earth, the sun, and the universe. For some, science is an adventure, but for all scientists it is also very hard work. Scientists try to describe as accurately as they can the world about them and in so doing need to measure it accurately.

This book is also about the kinship between scientists — that host of adventurous spirits — who worked in the past, are working now, and will work in the future.

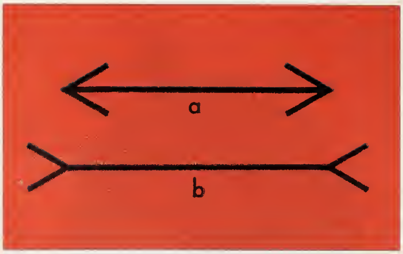
How do they work?

Why do they work?

What can *you* learn from the scientist's way of work so that you may work better — and live a better life?

It has been said that the person who will land on the moon is already born; possibly he is one of your classmates. And when this first "Columbus" of space navigation does land on the moon he will do so armed with the knowledge scientists have gathered, armed with their ways of work, and armed with their spirit of adventure.

Man, as you know now, is a great inventor. One of his greatest inventions is a way of work, sometimes called "scientific methods of work." Notice the phrase "scientific *methods* of work"; there are a number of methods, not just one. People say that these methods help scientists solve their problems with great accuracy. Let us look into the ways scientists work. Is their way different from the way other people work? Perhaps a study of the scientist's way of work will help you in your own.



1 Which line is longer, *a* or *b*? Now measure each with a ruler. Should you always trust your eyes?

ON BEING MORE ACCURATE

Take up a glass of water. How warm is it? You may guess. Now put a thermometer into it and read the temperature. You *know* now how warm it is to a fairly accurate number of degrees.

Measure the lines in Fig. 1 with your eyes alone. Which line is shorter, *a* or *b*? Now use a ruler. What do you conclude?

These examples are given merely to show you that there are times when you need to check your observations by a standard — here, a thermometer and a ruler — to be sure that your judgment has not

tricked you. An instrument accurately observed gives more reliable information on which more persons can agree, especially if they are trained. Measuring instruments are used in science to aid the observer, the scientist, in obtaining more accurate information.

Of course, you would agree that the more times a measurement is taken under the same conditions, the surer you will be of the result. For example, one scientist who was working on the temperature of a certain snake recorded these temperatures in his notebook for "one" measurement at that hour: 18.0° C. (centigrade), 18.1° C., 18.0° C., 18.1° C., 18.1° C. On the basis of other experiments he had determined that the temperature of the snake he was working with tended to be about the temperature of the room; in these observations the recorded room temperature was 18.0° C. These figures therefore showed the scientist that his measurements of the snake's temperature were fairly accurate; note that the temperatures were only 0.1 of a degree apart. Had they been, say, 18.0°, 18.5°, 18.7°, 17.8°, 17.5°, the scientist would have suspected something was wrong. Furthermore, these temperatures were taken at the same time, at two o'clock in the afternoon every day for four weeks. The five temperatures were then averaged together, and the average temperature was then used as the measure. Other temperatures were taken at other hours of the day.

This case for accuracy is typical of the way scientists work; they take many measurements in the same manner and under as nearly the same conditions as possible. As you have learned, scientists always take many observations before describing what they have observed. They take as accurate measurements as they need to, in order to make sure their observations can be relied upon. That is, they can be repeated under the same conditions with the same result.

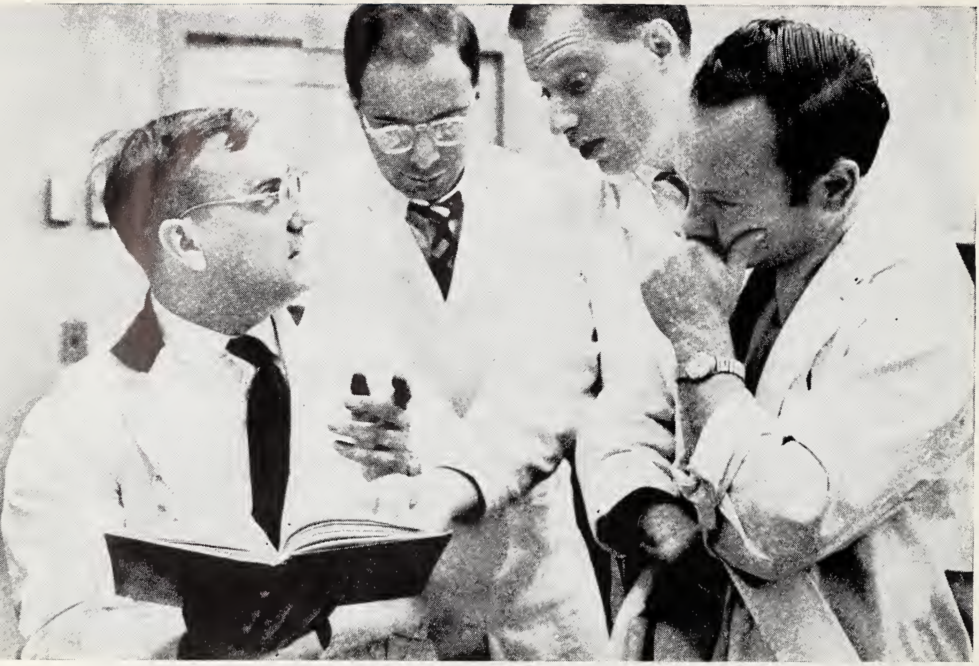
Yes, you could determine whether something is warm and something is cold, but a thermometer could tell you *how* warm or *how* cold. Similarly you might know that you are tall, but exactly how tall are you? In fact, do you have accurate measurements of yourself with regard to:

1. Height
2. Waist
3. Chest
4. Weight
5. Average pulse rate

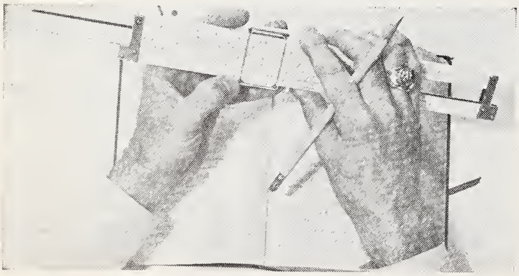
Try measuring these accurately.

In making these measurements you immediately note that you use one common kind of instrument to measure the first three of your characteristics and another for the fourth, but the instrument you use for the last one, *number five*, is different again. This must lead you to suspect that it is important to consider not only the accuracy of the instrument but also the kind of instrument you use.

To measure how fast your heart beats, you need a watch or a clock. You can feel the beat, called the pulse beat, on the inside of your wrist. Suppose, to measure your pulse beat, you use a clock that is twice as fast as the accurate time pieces. What would the count of your pulse beats be? Would this be an accurate figure to report to a doctor? Of course not. You would need a standard unit (a unit on which there is agreement everywhere), like the *second*, for the counting of pulse beats. You also need



Above, the book, the discussion, the well-stated question are significant tools of the scientist. *Below right*, so is the experiment. How much of a substance is taken up by a plant? Here radioactive phosphorus, a new tool, has been taken up by the leaf shown. The leaf placed on a photographic film has left a "photograph" of phosphorus concentrated in the veins but also diffusing out into the leaf.

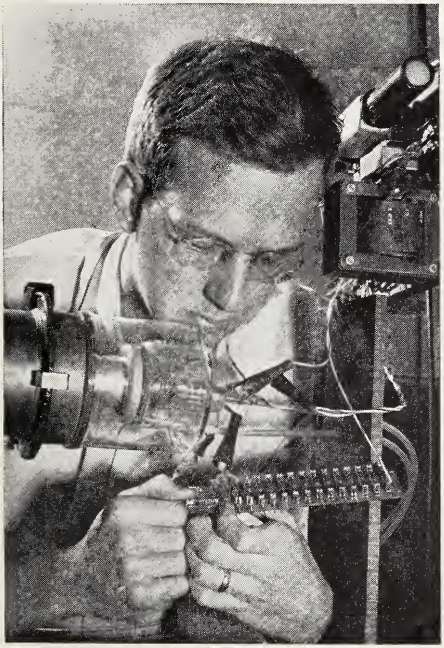


The scientist uses numbers — as well as words — in his research. Slide rules, computers, graphs, tables (in short, mathematics) are important tools in daily use.

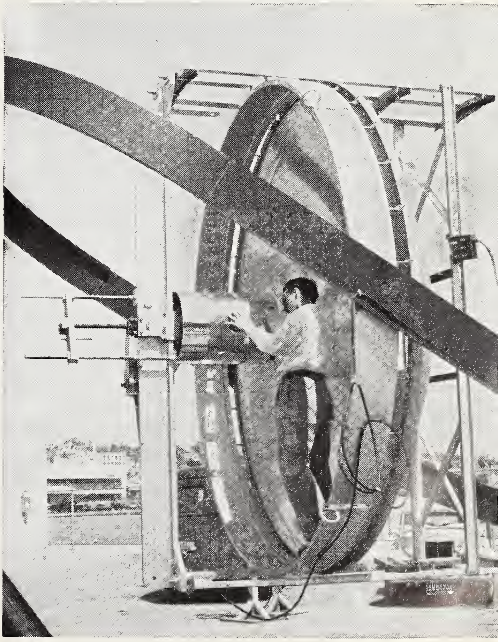
ADVENTURE IN SCIENCE

What would happen if the force of gravity were to be reduced to zero? Free floating, or *weightlessness*, results. Carefully conducted tests such as this one help scientists determine what will happen when space men meet such conditions in their space ships. It helps, too, to devise safeguards which may make space travel possible.

The frontier of discovery is always an adventure. Here Donald Janney, a graduate student at Stanford University, tests a six million-volt gun which will shoot electron "bullets" at deep-seated cancers.



This 120-inch solar furnace reflects the sun's rays from a large aluminum mirror to a dime-sized point. The furnace can develop a temperature of 8,500° F., about 85% that of the sun's surface.



a standard unit of length for your height, waist, and chest measurements, and a standard unit to measure your weight. Let us see how we develop a standard unit.

The Need for Units

If a friend said to you, "I was in a very large room yesterday," you wouldn't have much of an idea of how large the room really was, would you?

Mind you, your friend's statement is accurate and reliable. The trouble is that you don't know what he means by "very large." He has in mind a comparison which you do not have. So you are at a loss. You have no common object — no common unit — for comparison or agreement.

But if your friend says, "I was in a room about ten times as big as this one," you have a much better idea because now you have something in common. Both of you are thinking of the same unit.

How big is "big"? How small is "small"? Suppose by some bit of strange magic you and your neighbors could grow smaller until you had shrunk to the size of an atom — the tiny, invisible atom. Suppose you joined hands. Then *200 million* (200,000,000) of you, standing in a line, might just fit into the word *atom*. Even though this bit of pretending results in figures beyond your understanding, still it gives you an idea of how small an atom is. Even though an atom is so very small, there are parts within the atom that are far smaller. You may know that almost all atoms are made up of small particles called *neutrons* and *protons* near the center, and *electrons* towards the outside with a great amount of space in between (Fig. 140). You will learn more about these particles in Chapter 14. An electron is probably the smallest particle of matter. Yet a proton weighs 1,836 times as much as an electron. We *compare*, you see, the weight of the electron as a *unit* with the weight of the proton in the same unit of weight. We know, therefore, the weight of an electron — in this instance — only in comparison with the weight of a proton. We have used the electron, we might say, as a *standard* of comparison.

How far is far away? The problem of developing units for very large objects, or very long distances, is different from that of developing a unit for invisible objects. Suppose we wanted to find out how far a certain star is from the earth. We could measure the distance in miles. We know the moon is about 240,000 miles away from the earth while our nearest star, the sun, is at an average distance of 93,000,000 miles away. But another star, the next nearest to the earth, Proxima Centauri, which can be seen in the Southern Hemisphere, is about 24,000,000,000,000 (24 trillion) miles away. In the Northern Hemisphere, the nearest star we can see other than the sun is Sirius, the Dog Star. It is roughly 51,000,000,000,000 (51 trillion) miles away. You will learn more about these distances in the universe when you come to Unit 3.

It seems just as impossible to believe such tremendous distances as it was to believe the tremendous smallness — minuteness — of the electron. Our minds need a standard *unit* to help us understand, to tie these unbelievable measurements of great distance to more familiar ones.

Considering the immense distances between the stars (trillions upon

trillions of miles), scientists have agreed to measure distances in space with the unit commonly called the *light-year*. This is the distance light travels in one year. Let us see how they developed this measurement.

It had been known for some time that light given off by an object traveled at a fairly constant speed. Galileo, the great Italian scientist, had attempted to measure the speed of light and failed. In 1676, Roemer (RUH-mer), a Danish astronomer, *estimated* it at 186,000 miles per second.

Two American scientists, Michelson and Morley, in a famous experiment performed in California, accurately measured the speed of light. Light, they found, did travel at the speed of about 186,000 miles [1] per second — yes, per second — or about 7½ times the distance around the earth. (At the end of this chapter, in "Going Further," you will find a suggestion to help you discover an account of this famous experiment which determined for us this very important fact on which a very useful unit is based, the light-year.)

We know of nothing that travels faster than light, and the measurement of how fast it travels in a vacuum turns out to be always the same — a *constant* as scientists call it. Light travels 186,000 miles per second. This is one of the very important *constants* in science.

In one minute, therefore, light travels 60 seconds × 186,000 miles = 11,160,000 miles. If you have courage, divide 93,000,000 by 11,160,000, and you will see that light from the sun takes about 8 minutes to reach the earth.

Let us see if we can find out how far light travels in a year. A day has 24 hours, each containing 60 minutes. Thus a day has 1,440 minutes. A year has 365.25 days, or 365.25 times as many minutes, or 525,600 minutes. If you want to find out how far light can travel in a year, just multiply 11,160,000 miles, the distance light travels in a minute, by 525,600. You will find that the answer is about 5,880,000,000,000 miles. Thus nearly 6 trillion miles is the distance light travels in one year. This distance is

[1] More accurately, 186,284 miles per second.

AMERICAN MUSEUM OF NATURAL HISTORY AND LOWELL OBSERVATORY

2 The two lines point to one star out of hundreds you can see on a starlit night. A telescope will make this star and other nearby bodies seem closer. Which gives the more accurate observation, your eye or the telescope?

called a *light-year*. And so we see that Proxima Centauri is about four light-years and Sirius about 8½ light-years away, numbers stated in *units* that are easier for us to understand.

The light-year is thus based on a *standard unit* of measurement, the speed of light per second. In these days of the space exploration, light-years may soon be used as units of measurement as commonly as miles.

Of course, the basic units we commonly use in everyday life and in science are probably familiar to you. You may be able to measure length in either inches or centimeters, volume in pints or cubic centimeters, and weight in ounces or grams. However, if you do not know both the English and metric systems, you may wish to refer now to pp. 649–656 to review the basic units of measurement and some other information you will find useful during this year of science. We have placed this material on these pages so that you may refer to the information readily whenever you need it.

RECOGNIZING THE SCIENTIST

Having seen that accuracy is one of the first goals of the scientist, let us look at his other methods. One of the best ways of doing this is to study several early scientists at work.

Francesco Redi

Francesco Redi (RAY-dee), an Italian scientist, lived in 1670. In his time most people believed that the maggots of flies (so-called worms which hatch from flies' eggs) came from decaying meat. But Redi doubted that living things (the maggots) could come from a dead thing (the decaying meat). What did he do about it?

First of all, what he did *not* do is very important. He did not come to a conclusion just from talking it over with others. Instead, he began to look for the *evidence*, for the facts that would give him an answer to the problem, "Do maggots come from meat?" Read for yourself his own words, translated from the Italian.

Having considered these things, I began to believe that all worms found in meat were derived directly from the droppings of flies and not from the putrefaction [spoiling] of the meat, and I was still more confirmed in the belief by having observed that before the meat grew wormy, flies had hovered over it, of the same kind as those that later bred in it. Belief would be vain without the confirmation of experiment; hence in the middle of July, I put a snake, some fish, some eels of the Arno, and a slice of milk-fed veal in four large wide-mouthed flasks; having well closed and sealed them. I then filled the same number of flasks in the same way, and left these open. It was not long before the meat and the fish, in these second vessels, became wormy and flies were seen entering and leaving at will; but in the closed flasks I did not see a worm, though many days had passed since the dead flesh had been put in them. Outside on the paper cover there was now and then a deposit, or a maggot that eagerly sought some crevice by which to enter and obtain nourishment. Meanwhile the different things placed in the flasks had become putrid and stinking; the fish, their bones excepted, had all been dissolved into a thick, turbid fluid, which on settling became clear; with a drop or two of liquid grease floating on the surface. . . .

Leaving this long digression and returning to my argument, it is necessary

3 The scientist Redi wanted to know if maggots came from meat or from flies. Which jars are controls in this experiment?

to tell you that I thought I had proved that the flesh of dead animals could not engender [produce] worms unless the semina [eggs] of live ones were deposited therein. Still, to remove all doubt, as the trial had been made with closed vessels into which the air could not penetrate or circulate, I wished to attempt a new experiment by putting meat and fish in a large vase closed only with a fine Naples veil, that allowed the air to enter. For further protection against flies, I placed the vessel in a frame covered with the same net. I never saw any worms in the meat, though many were to be seen moving about on the net-covered frame. These, attracted by the odor of the meat, succeeded at last in penetrating the fine meshes and would have entered the vase had I not speedily removed them.

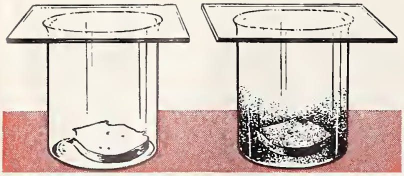
Redi's Plan of Work

Redi first studied the problem carefully. He made a plan for finding how the maggots got into the meat. In his own words, "I began to believe that all worms found in meat were derived directly from the droppings of flies and not from the putrefaction of the meat." Scientists call a good guess such as Redi's, which is based on a few facts or observations, a *working hypothesis* (hy-POTH-uh-siss). A hypothesis is but the beginning of the work a scientist does. It gives the scientist an idea of how and where to begin his work.

Then Redi began to gather and record more facts to find out if his hypothesis was a good one. He did this by *designing and carrying out many experiments* which would help him to get the facts he needed. He kept careful records, for he knew that the memory is often faulty.

Redi's Experiments

In one of Redi's experiments he prepared three jars with a piece of meat in each (Fig. 3). He left one open; he covered one with a kind of cheesecloth; and he made another airtight. He saw many times, not just once, that flies flew to the meat in the open jar and laid their eggs on it. These eggs hatched into maggots. Flies rarely flew to the airtight jar because, as Redi thought, the odor of decaying meat could not reach them. Flies flew to the jar covered with cheesecloth because the odor passed through the cloth. The flies, though, could not get into this jar to lay eggs on the meat. From many



4 Is moisture necessary to grow mold on bread? Which jar is a control?

observations, Redi concluded that maggots came from flies' eggs, not from meat. He needed all three jars to discover whether maggots came from the meat or from the flies' eggs. Can you understand why?

Recall that Redi had one jar in which flies were permitted to get to the meat to lay their eggs. The second jar was like the first except that the flies could not get to the meat to lay their eggs. Maggots appeared in the meat in the first jar, but they did not appear in the second jar. The second jar was an important part of the entire experiment. It was really an experiment in itself. It was the *control experiment*, sometimes just called the *control*. The control is a check. The control experiment keeps out, or eliminates, the cause or condition the scientist is investigating. Redi believed that *flies* were the cause of the maggots in decaying meat. Therefore, he kept out the flies (the cause he was investigating) in his control.

Do you think you can set up a control experiment? Try this one. You have seen moldy bread. Is moisture necessary in order for mold to grow on bread? Let us set up the experiment (Fig. 4). We keep a piece of bread out in the air until it is absolutely dry. Then we moisten it with water and place it in a dry jar. We cover the jar closely.

Now what is the control experiment? We do exactly the same thing — use the same kind of jar, the same kind of dried bread, keep both jars in the same place — with one exception. We do not moisten the second piece of dried bread. The effect of moisture is the condition we are investigating. Hence, we will leave moisture out of the control.

We will compare the two experiments after a week. Is this enough to come to a conclusion? Not at all.

We need to repeat the experiment *many times*. Of course, this investigation has been done many times. However, it is only after several repetitions of the experiments by many observers who confirm our results that we can come to a truly scientific conclusion.

Redi was not satisfied with doing just one experiment. Indeed, he repeated his experiment many times. He did not come to his conclusion from one fact found by one experiment. He could always go back to his careful records for the data of his previous experiments.

Finally, Redi did not keep his discovery secret. He published a report of his conclusions so that other scientists could repeat his experiments and thus check his work.

In short, Francesco Redi used several procedures for getting at the truth. First, he carefully thought out his problem. He carefully thought out a working hypothesis and made a careful plan of experiment to test his hypothesis. Second, he made many observations to help him to get at the facts necessary to test his hypothesis. Third, he came to a conclusion only after many observations, only after he had gotten many facts by repeating his experiments many

times. He tested his conclusions time and again. Fourth, he published his results so that other scientists could repeat his experiment and check his results.

Are these methods to be found in the work of other scientists? Let us look at another scientist, to check our observations of the methods of the scientist.

Recognizing a Scientist — Antoine Lavoisier

Some 175 years ago, it was believed that when a substance burned it lost weight. It was thought that a fiery substance called phlogiston (floh-JIS-tun) went up in the air. And this seemed perfectly reasonable. For instance, when a huge log of wood burned down, all that was left seemed to be the ashes, which could be carried out in a pail. A grown man had all he could do to carry the log into the room, while a child could carry the ashes out. However, on the basis of certain observations, Antoine Lavoisier (la-vwaz-YAY) believed that when a substance burned it gained weight, not lost it. This was his working hypothesis. How did he go about testing this hypothesis?

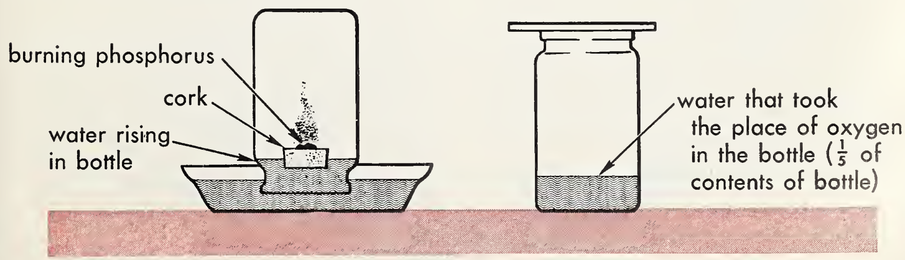
Lavoisier planned several experiments to answer the question, "What happens when substances burn?" He burned sulfur, phosphorus, mercury, and tin (Fig. 5). When he burned these substances in a closed vessel, he found that they combined with about one-fifth of the air in the vessel. (You know from your previous study of science that this is the amount of oxygen in the air.)

He also found that, in burning, these substances gained weight. He discovered this by weighing the substance carefully before and after burning. He did these experiments many times, observing carefully and keeping accurate records. Thus he came to the conclusion that when substances burn they gain weight by combining with a portion of the air. And he published his conclusions.

When we look closely at Antoine Lavoisier's work, we find the same pattern which we saw in Francesco Redi's work. We find:

1. Careful planning to solve a problem. This includes a working hypothesis or several hypotheses.
2. Careful observations and recordings of facts found through experiments repeated many times. The hypothesis is proved or thrown out on the basis of the facts.
3. Conclusions drawn only from accurate observations.
4. Publication of the work so that other scientists might prove the results for themselves if they wish.

5 An experiment to find out how much oxygen there is in air. Burning phosphorus combines with oxygen. The water rises to take the place of the space left when the oxygen is used up.



These methods used by Redi and Lavoisier seem entirely reasonable, do they not? They also appear simple to follow. If you examine carefully the methods they used, you see that there appear to be key steps *after the problem has been set.* These are:

a. Getting a good working hypothesis.

b. Planning an experiment to get the facts (observation) needed to prove or give up or change the hypothesis. Often the experiment has a *control experiment* as part of it (p. 21). Only by accurate observation can a hypothesis be proved, or found to be wrong or in need of change.

One careful student of the method scientists use has offered this definition. He calls the scientific method "the method of proving hypotheses." Whether we agree with his definition or not, he has underlined an important part of the scientific work, namely, proving the hypothesis through careful observation.

Dr. James B. Conant, not long ago President of Harvard, a scientist himself and a student of the ways of the scientist, thinks the scientist is mainly concerned with ideas. These ideas have to do with the way the world works. Dr. Conant thinks that once a scientist gets an idea of how things work (such as Lavoisier's idea of what happens when a material burns), he may then plan an experiment.

In planning his experiments, the scientist uses many methods. For instance, he may use his *common sense* as Redi did. After all, you might say it was just common sense for Redi to use meat in his jars. It was just common sense for him to cover one jar to see whether flies developed in that one (p. 21).

Another method a scientist may use is the *try it and see* approach. Like Lavoisier, he may say, "Let's see what happens when I burn mercury in air." The "try it and see" or "trial-and-error" method is commonly used in our laboratories.

Also, a scientist may make a *chance discovery.* That sometimes happens. Perkin, as you will read later (p. 29), is said to have discovered by chance how to prepare new dyes for coloring cloth as he was working in his laboratory. But you will also learn, as you read on in this book, that only trained people can take advantage of "chance." Untrained people let the chance — the great opportunity — slip by. Perkin had trained himself to recognize "chance discovery."

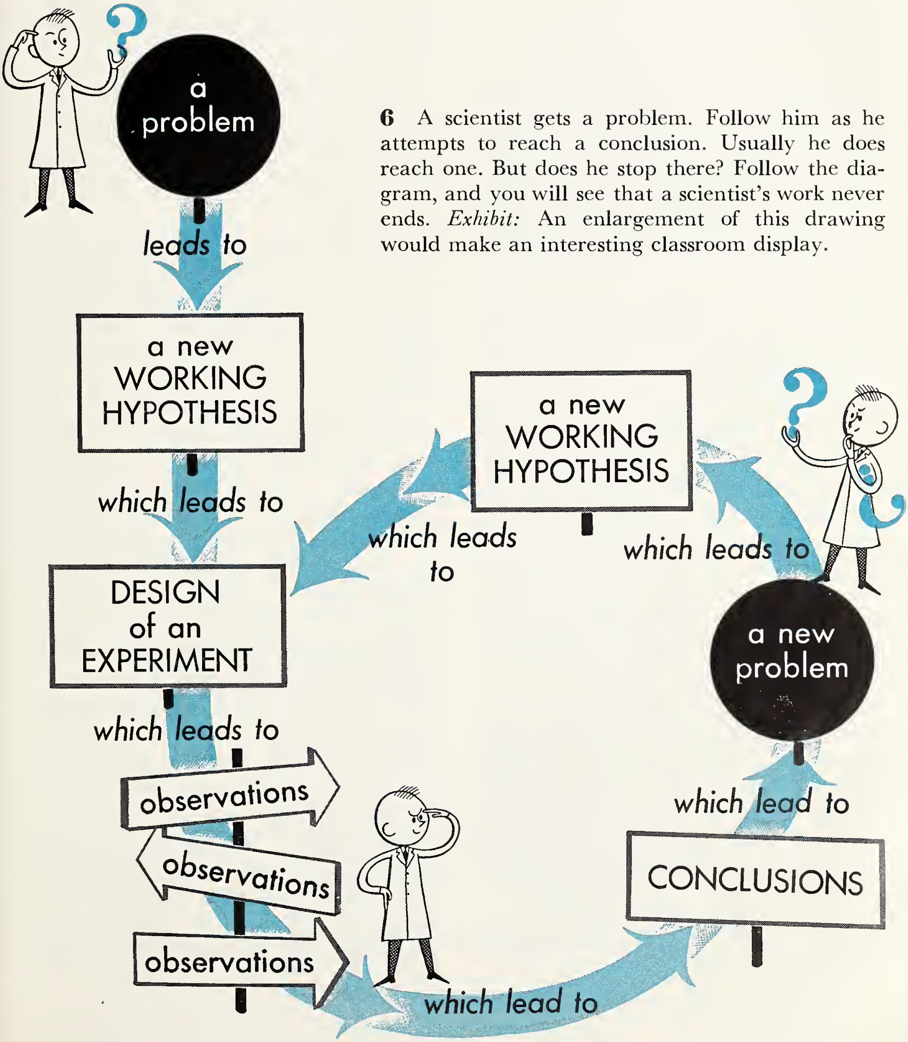
No matter what methods a scientist uses, Dr. Conant would say, there is still one thing which seems to be a part of his way of work. A scientist doesn't stop with his conclusions. A scientist's conclusions, Dr. Conant thinks, lead him only to new problems.

Put very simply we can diagram Dr. Conant's idea somewhat as in Fig. 6. In other words, *the main thing that is characteristic of the way of the scientist is that his work never ends. His conclusions lead only to further problems.* These lead again to new working hypotheses, to new experiments, to other conclusions. These then lead to other problems. There is no end. If the scientist dies or stops work for one reason or another, others keep on investigating the ideas.

What most other workers do is, on the contrary, usually an end in itself. They build a house, for example. That is an end in itself. Once the house is built, the job is at an end

(except for small repairs). Once a picture is painted, the job is at an end. Once a machine is built, the job is at an end (except always for small repairs). There are, even with houses and machines, problems that call for the work of scientists — as you shall see later in this book. Look again at the diagram in Fig. 6. Can you see the scientist's work is never at an end because one idea leads to another?

Professor P. W. Bridgman, who has studied the methods of scientists, thinks that one cannot really define scientific methods. One of his favorite definitions is that science means *doing one's best with one's brain, no holds barred*. What he is really saying is that different scientists work in different ways, that there is really no one way



6 A scientist gets a problem. Follow him as he attempts to reach a conclusion. Usually he does reach one. But does he stop there? Follow the diagram, and you will see that a scientist's work never ends. *Exhibit:* An enlargement of this drawing would make an interesting classroom display.

in which scientists solve problems in which they are interested. In other words, there are many ways in which scientists work. There are many, many different ways in which scientists try to find out how the world works. On this most scientists agree.

How Scientists Work: A Summary

Now that we have seen how some of the great scientists work, let us summarize their ways of working.

First, a scientist starts his work by setting forth his problem clearly. He may get the problem by reading about it, by observing, by listening to others, or by thinking of it himself. Lavoisier, it is thought, got his problem "What happens when substances burn?" from reading the work of other scientists.

Second, a scientist reads the works of other scientists or talks with them. Lavoisier read others' works; thus, he knew of the work on phlogiston.

Third, a scientist carefully plans to use all possible methods which will help him solve the problem he has set for himself. In this planning, a scientist tries to "guess" at a possible solution of the problem. Such an "educated guess" is called a hypothesis (a working hypothesis). The scientist plans his experiments around this guess. For instance, Redi guessed that the maggots in the meat came from flies which laid eggs on it, not from the meat itself. If the facts that a scientist gathers do not support his hypothesis, he will throw his hypothesis out or change it, or form another. In other words, a hypothesis helps give direction to the scientist's experiments.

Fourth, a scientist repeats his experiments and records his observations and measurements many times before he is satisfied with a conclusion. Lavoisier burned mercury, tin, wood, and other substances before he came to a conclusion about burning.

Fifth, a scientist generally makes his methods and conclusions known so that other scientists may check his results.

Does the successful completion of an experiment end the work of the scientist? On the contrary, as you have read, it leads to more ideas and more problems.

It is clear, then, that it is the methods they use which tell whether men are scientists — not where they work or what problem they choose to investigate.

Putting the Facts Together

After having read of the importance of getting the facts, you may be surprised to learn that scientists want more than facts.

When Lavoisier became interested in the problem "What happens when things burn?" he found that oxygen combined with the substance being burned. That was his conclusion. It was an important fact to know. But no sooner had he discovered this than he asked "What does this fact mean? Does it fit in with other facts?"

Thus he tried to find out how other substances burned. He studied the combining of oxygen with different metals. Then he related this idea of the burning of wood to the combining of oxygen with food (burning within the body). He tried to relate the facts he discovered to each other, to find out whether there was any order into which the facts might fall.

When facts in large number fall into some order, scientists try to form

Scientists at Work

1. A scientist starts his work by getting an idea. He may decide to find out whether his idea is "true." Thus he may state what he wants to find out about the idea as a "problem."

2. He tries to discover all that is already known about his idea, or problem.

3. A scientist carefully plans to use all possible methods to see whether his idea is true.

4. A scientist repeats his experiments and records his observations many times.

5. A scientist generally publishes his experiments and conclusions for other scientists to check.

a *theory*. A theory tries to explain the facts discovered. A theory, then, is a large idea of how the world works.

For instance, on the basis of all the facts Lavoisier discovered about burning, he formed a theory of burning. His theory states that when a substance burns in air it combines with oxygen. His theory of burning is a large idea of one way the world works.

Lavoisier's experiments supported his theory. Furthermore, on the basis of this theory of burning one could predict the results of new experiments on burning. For instance, if we burn the metal magnesium (mag-NEE-sheeum), we may predict that it will combine with oxygen. And it does. If it did not, we should have to change the theory of burning.

Here's another theory, or large idea, of the way the world works. On the basis of many experiments and observations, scientists have stated the theory that all living things come from other living things like them. We may, therefore, predict that any given thing, let us say a germ, must have come from another germ like it. One worm comes from other worms like it. If this were not so, then we should need to change the theory. A theory, you see, puts together many related facts in some sort of order. It has been said that scientists are always on the search for order in the universe. Put another way, they ask, "How does the world work?" It is the business of scientists to find out. And they need the facts.

However, before facts can be put in any order, they must be discovered. That, too, is the business of scientists.

These scientific ways of work you have been reading about help scientists, singly or in teams, to look for the facts, check the facts, conclude only from the facts. These methods enable them to put the facts into theories — the large ideas which explain the way the physical world works. By these methods, these ways of work, scientists try to solve problems of life and living. The methods are troublesome, perhaps. But they are certain and trustworthy. The methods are the foundations of science.

WHO BECOMES A SCIENTIST?

Next time you go to school, look about in your classroom and ask yourself, "Who in the class is likely to become a scientist?" Will it be you? This is a hard question to answer because so far no one has found good methods for selecting scientists. But we can begin to search for an answer by asking, "Who can use these scientific methods?"

Citizens Use Scientific Methods

People who are not scientists may use scientific methods. For example, let us go along with Mr. X, who goes for a Sunday drive. Along the way, the engine stops running and his car stops. Notice the way he behaves. He checks every trouble spot — the gasoline supply, the fan belt, the battery, the spark plugs, the oil, the water, until he finds what is wrong. Then he knows what to do.

He has gone over the many facts from which he can get at the cause of the trouble. Of course, Mr. X was concerned with a simple problem, but he used careful observation, a scientific method of finding a solution for his problem. Mr. X is not a scientist, but he is using one of the methods of the scientist — observing accurately, then "trying it to see."

Mr. Y is ill. He has a bad cough. He doesn't hang a walnut around his neck as his superstitious neighbor advises him to do. He doesn't try Foolum's Cough Medicine. He doesn't ask his druggist. He goes to a trained expert, his doctor. The doctor uses instruments to get at the true cause of his illness. If the doctor doesn't know, he calls in another expert. Mr. Y is not a scientist, but he is using one scientific method — the common-sense approach. He goes to an expert.

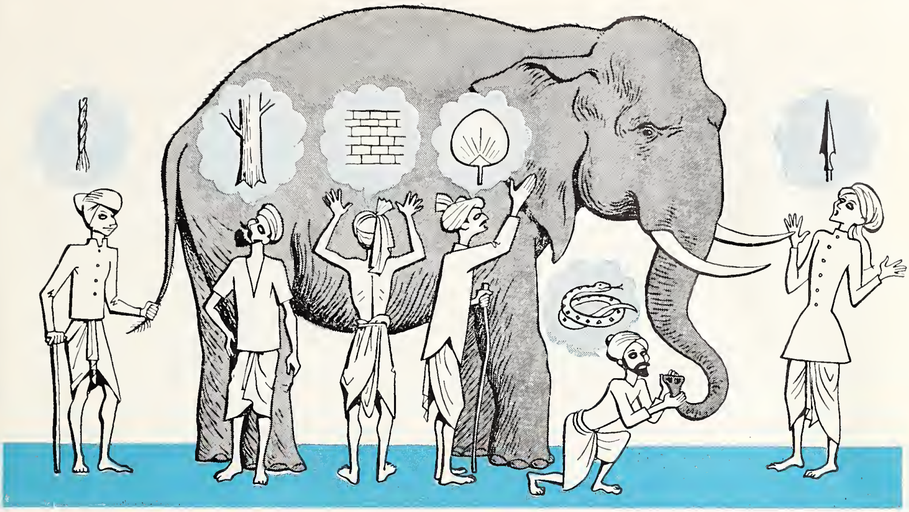
Mr. L is a farmer. His agricultural magazine has an advertisement which states that Magno-Fertilizer is better than any fertilizer known. Mr. L could throw out the fertilizer he has been using. But he does not. He buys a few sacks of Magno-Fertilizer and tries it on several acres of wheat, but treats the other acres as before. (He thus uses a control.) He also asks the county agricultural expert. He also writes to the state agricultural station. Farmer L is not a scientist, but like Mr. Y he is using scientific methods, the common-sense approach, as well as "try it and see."

If you try to come to a solution of any problem from one fact or only a few facts, you may find yourself in the position of the six blind men who, the story tells us, were trying to discover the nature of an elephant. They had never seen one. Each one came to a different conclusion (Fig. 7).

Whenever you do away with guesswork, superstition, or prejudice and use all the facts you can get, plus the help of experts, to solve your problems, you are using scientific methods. You may not be a scientist, but you are acting intelligently in using science and its methods to solve your own personal problems. Can you see why the methods of science have also been called the Methods of Intelligence? Dr. Bridgman of Harvard uses this term to describe them.

Science Experts

You have noticed that Mr. Y and farmer L went to experts. This is because no one can hope to have the knowledge necessary to solve every one of his problems. These experts may not be research scientists who make original discoveries of facts. They do have the facts and know the recent discoveries in their field. They know how to apply them to solving problems. Some of these experts are doctors, dentists, horticulturists, laboratory technicians, science teachers, engineers, and inventors. Can you mention others? These people have spent years of their lives training themselves to become skillful



7 Six blind men each get a different idea by touching a part of an elephant. Why did each man state a different conclusion about what an elephant is like? Is one observation enough for an accurate conclusion? *Project:* Collect clippings from newspapers and magazines to show a conclusion that has been reached from only one observation. Post on a bulletin board.

in using the facts of science, in solving problems you cannot solve yourself. A doctor, for example, spends four years in college, four more years learning medicine, and several additional years as an assistant to other doctors, that is, as an intern in a hospital learning to apply his knowledge.

It may be, however, that you will become a research scientist. Why not?

Research Scientists

One hundred years or so ago, a person became a scientist as soon as he began to make discoveries. William Henry Perkin (1838–1907) was such a person.

Perkin, an English schoolboy, was seventeen years old when he made one of the important discoveries of the nineteenth century. His teacher, knowing of young Perkin's interest in chemistry, suggested to him that he try to make *quinine* (KWY-nyne). As you may know, quinine is an important drug used in destroying the germs of malaria. With his teacher's help, Perkin began to work after school hours. Experiment after experiment failed. But one day, as Perkin began to wash out one of his test tubes, he noticed a beautiful color as the water dissolved the sticky mass of coal tar at the bottom of the tube. He repeated his experiment again and again. Each time he got a beautiful purple color called *mauve* (MOHV).

Perkin and his teacher were excited. They knew that most dyes then in use were gotten with great difficulty from certain animals and plants. Perkin worked harder, and he came to his teacher for help in solving many of the chemical problems facing him. So it was that Perkin, trying to make quinine, in 1856

made the first dye, mauve, from coal. Ten years later, he succeeded in making another dye. Perkin had laid the foundation of the dye industry. Over ninety years later, in 1947, Dr. Robert Woodward of Harvard, following some of Perkin's methods plus some of his own, made quinine.

Dr. Woodward, although just as intelligent as Perkin, could not start in the same way. At present the field of science is so complex that a great deal of training is needed before anyone can become a trained research scientist. Dr. Woodward went to college for four years. That was only the beginning. Then he worked to get a doctor's degree in chemistry.

In order to get a doctorate in science, a student must show his ability to do original research. Not only must he make some original discovery, but he must also advance in his studies. This usually takes four to six years after college. So you see that nowadays a trained research scientist is tried and tested before he enters upon his work of discovery.

A research scientist, then, is one who tackles unsolved problems in science. Sometimes physicians or engineers become research scientists. They discover that they are more interested in searching for the facts than they are in applying them. They find enough work, for there are ever-widening fields in science. Scientists are just beginning to discover the kind of world in which we live. The science of the atom is still very young. We are just beginning to find substitutes for wool, for cotton, for wood, and for metals. We will probably see a shortage of scientists for many years. At present, we need more engineers, for example, and more research scientists. Is science for you?

Science and You

You may become a research scientist, or you may enter a profession which applies the findings of the research scientist. You may enter a nonscientific profession or business. Whatever you do, you will find that science affects you. For science may be thought of in these ways. It is a *body of great ideas concerning the way this world works.* This book deals with a number of these great ideas. These ideas (such as the one that all living things come from other living things) have been developed through the work of many scientists over many years.

Science is a body of *tried and tested information* which you will need to use daily throughout your life. For instance, you use scientific knowledge about diet and your personal health every day.

Science is a *body of inventions* which has improved and will continue to improve your living. The telephone, radio, automobile, airplane, new types of cloth such as nylon and Dacron, nonbreakable materials called plastics, and new drugs, such as penicillin, are just a few examples.

Finally, science is a *body of methods of getting at the evidence* (scientific methods). You have already used some of these methods and should use them whenever possible to solve problems and to get the facts so that you can act wisely.

You are living in a world where science plays an increasing part in your life. And as you read this book you will see how science affects you in your daily living. Now you know something of the way the discoveries of science have been made. This is only a beginning. Throughout the

book you will learn how truly exciting the work and methods of scientists can be.

Look around again in your classroom. Which of you will become scientists? Several of you may. Every one of you, in some way, will be affected by science and scientists. And every one of you will need to know how to use scientific methods to get at the evidence. For if you live by the evidence, your actions will be more intelligent. You will be using science for better living.

LOOKING BACK

Tool Words

1. *Hypothesis*, *theory*, *fact*, *control experiment*, and *conclusion* are five important although common words in the language of science.

Test yourself on whether you can pick out Redi's hypothesis, and at least two facts he knew, from his description of his experiments on p. 20. List one control experiment he used.

Now check your choice against the text on p. 21.

2. On the basis of Redi's observations, which of the following might have been the theory he proposed?

a. Living things come from nonliving things.

b. Living things come only from living things.

c. Flies come from maggots.

Test Yourself

1. Write a short article for your school paper (or for a report to your class) on "The Methods of Intelligence," the term which one scientist thinks describes the way scientists work.

2. A scientist has 100 guinea pigs for an experiment. He wants to find out whether the *X* germ causes a certain disease. He can inject the germ if he wishes. How would you use the guinea pigs in an experiment?

GOING FURTHER

Adding to Your Library

Is your future in science? These books will help you decide. Naturally, you will get the advice of your parents, your teacher, and someone now working in the kind of job you would like to have.

1. *Career Opportunities in Biology* by Russell B. Stevens, Row, Peterson, and Co., 1911 Ridge Ave., Evanston, Ill., 1956.

2. *Careers in Natural Sciences* by Robert Shosteck, B'nai B'rith Vocational Service, Washington, D.C., 1954.

3. *Shall I Study Chemistry?* American Chemical Society, Washington, D.C.

4. *Careers in Chemistry and Chemical Engineering*, Case Institute of Technology, Cleveland, 1954.

5. *A Career in Physics*, Case Institute of Technology, Cleveland, 1954.

6. *Your Career in Physics* by Philip Pollack, Dutton, New York, 1955.

7. *Careers and Opportunities in Science* by Philip Pollack, Dutton, New York, 1954.

8. *Chemists, Mathematicians, Electronic Scientists, Metallurgists, Physicists*, Announcement No. 46 (B), U.S. Civil Service Commission, Washington, D.C., 1956.

9. *Geologist* by Warren Bracket and H. Alan Robinson, Occupational Abstract No. 196, Personnel Services, Inc., Peapack, N.J., 1956.

10. *Careers in Science Teaching*, The Future Scientists of America Foundation of the National Science Teachers Association, NEA, Washington, D.C., 1955.

11. *Encouraging Future Scientists: Keys to Careers*, National Science Teachers Association, NEA, Washington, D.C., 1956.

12. *Professional Opportunities in Mathematics* by Professor H. M. Gehman, Mathematical Association of America, University of Buffalo, Buffalo, N.Y., 1954.

13. *Your Opportunities in Science*, National Association of Manufacturers, New York.

14. *Should Your Child Be a Dentist?* New York Life Insurance Company, New York, 1955.

15. *Should Your Child Be a Doctor?* New York Life Insurance Company, New York, 1955.

16. *School Subjects and Jobs* by Lester J. Schloerb, Science Research Associates, Chicago, 1950.

17. *General Electric's Answer to Three Whys (Why Study Math? Why Study Science? Why Look into Engineering?)*, General Electric, Schenectady, N.Y.

18. *Discovering Your Real Interests* by Frederic Kuder and Blanche Paulson, Science Research Associates, Chicago, 1949.

19. *SRA Occupational Briefs*, Science Research Associates, Chicago.

20. *Your Future in Science* by Morris Meister and Paul F. Brandwein, Science Research Associates, Chicago.

21. *Wider Than the Sky: Aviation as a Career*, by Charles M. Daugherty, Harcourt, Brace, New York, 1958.

Careers for You

One of the most important things you can do in junior or senior high school is to find out what you want to do as your lifework. Perhaps you may want to go into some field of science.

Form a committee on Vocations in Science. Ask your teacher to reserve for you a place on the bulletin board. Paint a sign *Careers for You*. Under this title list different jobs in science, such as:

Engineering: chemical, civil, mining, electrical, automotive, and aeronautical.

Teaching and research: science teacher, physicist, geologist, biologist, and chemist.

Medical: doctor, dentist, nurse, X-ray technician, and laboratory technician.

Agriculture: farmer, horticulturist, plant and animal breeder, forester, and county farm agent.

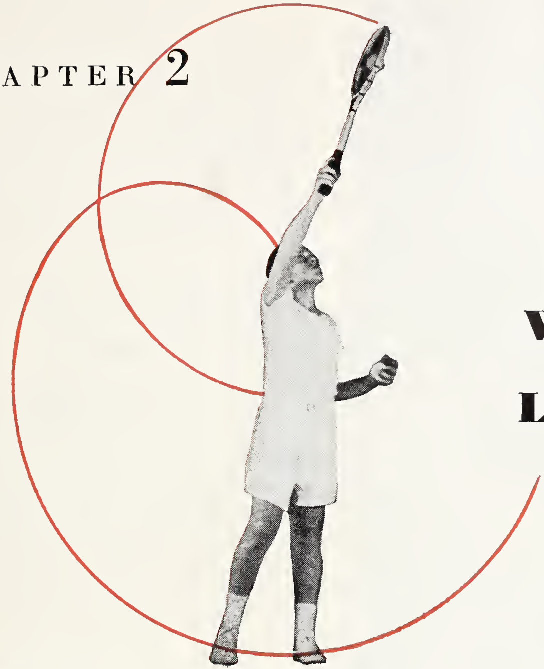
Special fields: entomologist (insects), ichthyologist (fishes), herpetologist (reptiles), ornithologist (birds), astronomer (the universe), and meteorologist (the weather).

For information about many positions in government service, write to the Dept. of the Interior, Washington, D.C. The department will send you the requirements for the positions of Junior Biologist, Junior Chemist, Junior Geologist, and Junior Physicist, and many of the other positions listed above.

Your library will have many good books on vocations in science. You might also try to get some of the books and pamphlets listed here.

CHAPTER 2

Ways of Learning



Do this. 2 × 2 × 2 × 2. Is your answer 16? You are the only kind of living thing that can do this. Why? You have a brain which helps you learn, imagine, and invent. Yes, in this chapter you shall invent.

HERE YOU SIT. It seems as if you aren't doing very much. Yet you are about to do something no creature other than man can do as well. Do you know what that is? Find out for yourself by following these directions.

Do not look at the next page now — not until you have finished the next paragraph.

On the next page are two pictures of what man has been able to do even though his body was not built for doing them. Can you get an idea of any of the things in the pictures without looking at them? Start by making a list of the way man's intelligence has helped him to do things which his body could not do by itself. Now check your list against the pictures on the next page. Have you listed any of the things pictured?

Do you know what you were doing by *thinking* of your list, by imagining what was on the other side of this page? You were using your brain in a way no other living thing can. In much the same way, man, by *thinking*

U. S. NAVY

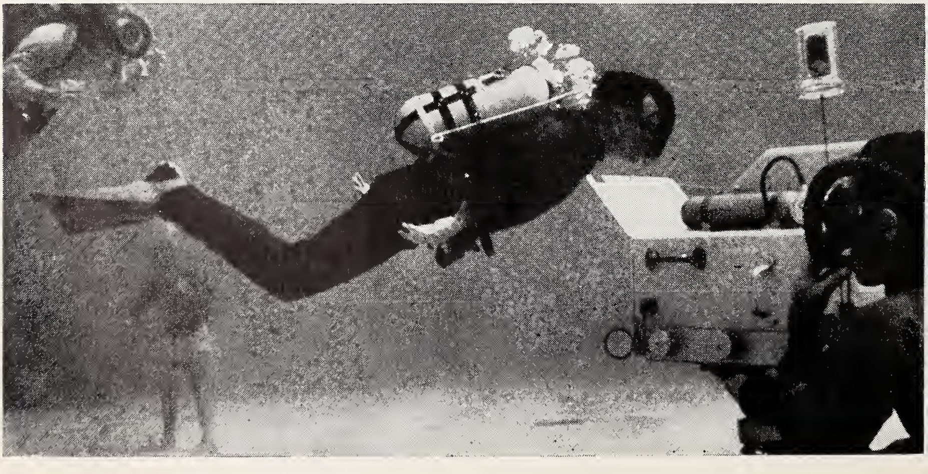
and imagining, used his brain to help him do the things pictured on this page. The way he can use his brain makes modern man able to do things no other creature can do. But his brain alone is not enough. He has certain other special physical traits — really special parts of his body — which help him to use his brain well.

MODERN MAN AND HIS SPECIAL TRAITS

You are a good example of modern man. Scientists say all of us who are on earth today belong to one kind of man, modern man. You have certain special physical traits which make you a modern man. These special traits set you apart from any other living thing.

8 Man is not able to stay long under water nor fly high and fast without the help of things he has invented. *Exhibit:* On your bulletin board post pictures (like the ones here) to show how man has conquered his surroundings.

BY LIFE PHOTOGRAPHER
PETER STACKPOLE, © TIME, INC.



Your Flexible Thumb

Have you ever looked at your thumb carefully? Touch your right little finger with your right thumb. Easy? Yes, but you are the only living creature that can touch thumb and fingers easily. Suppose you couldn't? You could not use a pencil well. Try writing without using your thumb; just hold it out straight as if it could not touch your other fingers. Try threading a needle without using it; it is very hard to do these tasks without using your thumb. You can see that the thumb can be moved to touch your other fingers. This physical trait, the way you can move your thumb, helps you, modern man, to use tools as no other living thing can (Fig. 9).

STANDARD OIL CO. (N.J.)

9 Could this scientist use this apparatus without her thumbs? Try threading a needle or writing your name without using your thumbs.

Passing Along What You Know

Can you imagine yourself without speech, without being able to make your wants known to others, to speak to your parents and friends? Your voice box is a very important part of your physical traits, those special traits of modern man.

Through his voice box, through his speech, modern man tells to others his wants, his hopes, the ideas he has thought of. He can teach others.

Man's ability to speak helps him to pass on what he learns to the next generation. When, long ago, man invented writing, he was able to record his speech and pass his knowledge on in a better way to his children and his children's children. Any new ways of doing things could be written down accurately; new inventions could be passed on; so could stories; so could man's history. As you *read* this book, you are taking part in one of man's most important ways of passing on what he knows to you, to the new generation.

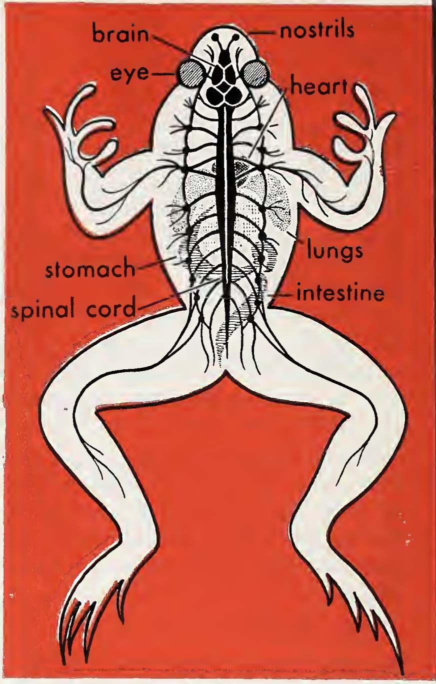
You know that man has advanced to his present level because of his brain. However, he didn't advance just because he *had* a brain. He *used* it. *He used it to learn.* He used it just as scientists use their brains to solve their problems.

Sir John Lubbock had a dog that learned to run to his food or water when he saw a sign EAT or DRINK. As you will learn later from some of Dr. Pavlov's interesting experiments, dogs can learn. In experiments with

laboratory animals we learn something about learning — one of the most important things man does. The important word in the sentence you just read — *learning* — is the key. In common with all other men you owe much of what you are to learning. True, animals are able to learn, but only in a small way. But man is different from other animals mainly because he is able to learn easily and quickly, and to use what he learns in reasoning and making decisions.

BEHIND YOUR LEARNING

First, let us examine the part of your body where learning takes place. That part of your body is the nervous system. Your nervous system has a lot to do with the way you learn, and with the way you know about the things that happen around you.



10 When you dissect a preserved frog, you will find nerves leading to all parts of its body. What do nerves do?

Your Sense Organs

You know of your surroundings through your senses. You are always getting *stimuli*[1] (STIM-yoo-lye) from your surroundings (called your environment). Anything in the environment to which plants or animals react is a stimulus. Light and sound are two kinds of stimuli. Any reaction to a stimulus is called a *response*. Jumping up to the slam of a door (stimulus) is a response.

No doubt you have realized that you are never free from stimuli. Light is reaching your eye, and sound is reaching your ear, now. You can see why the eye and the ear are called *sense organs*. An organ is a part of the body. And a sense organ is a part of the body which senses, or receives stimuli coming from your surroundings. Your sense organs, for instance, receive the stimuli of light and sound, as well as of other stimuli.

Touch your knee. Touch your head, your elbow, your cheek, your hand, your toe — any part of your body. You feel the touch. You are stimulating the sense organs in your skin. These sense organs receive the stimuli due to pressure. There are also sense organs of pressure and pain in other parts of your body. Thus you may feel a stomach-ache. The sense organs inside your body warn you that your organs inside are not

[1] Singular, *stimulus*.

working properly. Whether you are awake or asleep, your sense organs inside your body are receiving stimuli.

Next time you eat, ask yourself, "How do I taste my food?" You will realize that there must be sense organs in your mouth. Actually sense organs for taste are found in your tongue. As you smell food, you realize that your nose has sense organs as well.

These, then, are your chief senses: sight, hearing, taste, smell, and touch (feeling objects, feeling changes in temperature). With these sense organs, you know of the things around you. With them you recognize your friends, your home, danger, or safety. With them you observe carefully.

How do stimuli lead to responses?

Your Nervous System

Let us look at a frog for our study of the nervous system. Suppose we look inside a preserved frog. Once we get past the skin and push aside the intestines, we see long shiny thread-like structures along the backbone. These are the *nerves*. As we look, we find these nerves everywhere — leading to front and hind legs, to all parts of the frog's body (Fig. 10), much as they do in yours. Where do they come from? Where do they lead?

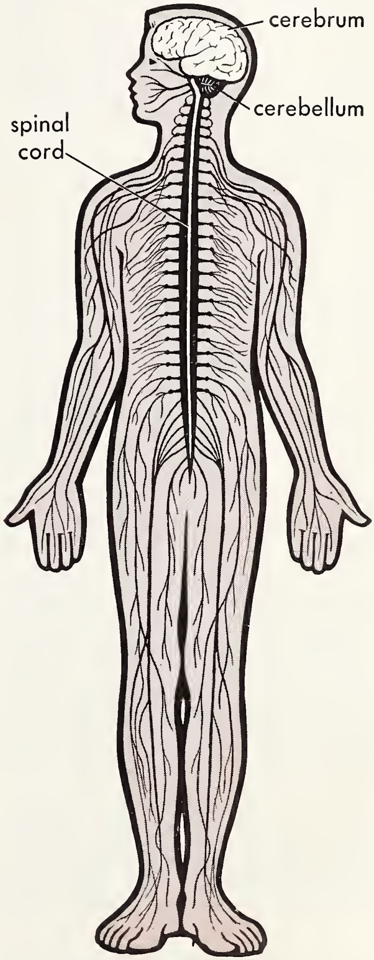
By tracing these nerves we see that all of them come from or lead to the long spine and the bony brain box. It is somewhat the same in man.

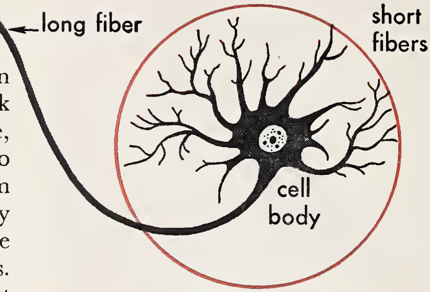
When you look at Fig. 11 you will see the plan of man's nervous system. Nerves lead from the spinal cord or from the brain to each part of the body. Then they lead from each part of the body back to the brain or spinal cord. The brain and spinal cord seem to be the centers of this system of nerves.

Brain and Nerves

Let us look at a bit of brain or spinal cord of an animal and examine it carefully under the microscope. The bit of brain is prepared for examination by specially trained people. They cut it into very thin slices

11 Can you see why a touch on your hand is felt by you in your brain? All parts of your body are connected by nerves.





and then stain it so it can be seen under the microscope. When we look through the microscope at the tissue, we see a number of *nerve cells*. We also see there the fibers which lead from them. If we were to examine any part of a plant or animal body, we would find cells of different shapes. Each one is microscopic in size; that is, it can be seen only with the microscope. But it is these tiny cells which are behind all the work your body does. At present, it is enough to know that the nerve cells with their fibers make up the nervous system. They are behind the way you think and the way you act.

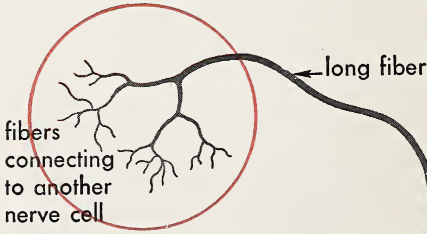
When we study one nerve cell, we see that it has a long fiber at one end and short fibers at the other. It looks like the one on this page. No matter what part of the nervous system we examine, we find these cells or their fibers. What happens when a nerve reacts to a stimulus is not entirely known, but something does travel from one nerve to another. Scientists call whatever travels from one nerve to another an *impulse*. The nerve cells send impulses to each other by means of the fibers at their ends. These fibers do not actually touch but are so close to each other that an impulse can travel from one fiber to another.

Thus all nerve cells connect with each other. There are millions of these connecting nerve cells. Thus a stimulus from any part of the body can reach any other part of it. In the spinal cord and brain, the nerve cells connect with each other by their connecting fibers. Outside the spinal cord and brain, certain long fibers are grouped together to form nerves. Each nerve is made up of thousands of nerve cells bound together in a bundle, much as a cable is made up of separate wires.

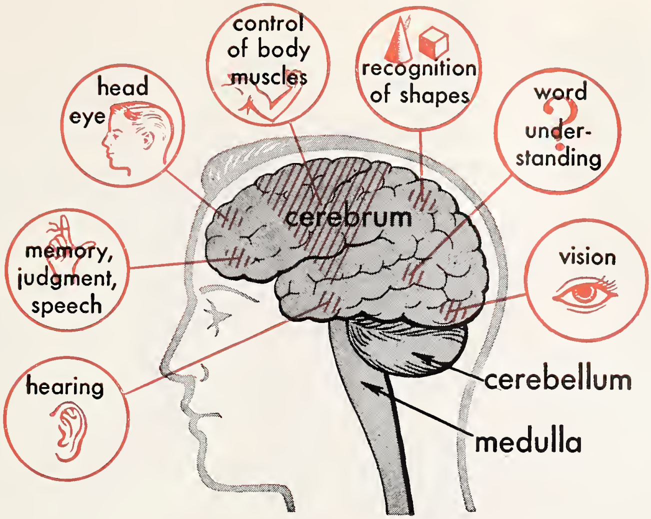
Look at the system of nerves in the human body (Fig. 11). There are nerves going to every part of it.

Your Brain — Center of the Nervous System

Here is a friend writing the chemical formula for water (H_2O). Here is a student solving a problem in algebra; he finds that since $x^2 = 16$, $x = 4$. Another student is memorizing Lincoln's Gettysburg Address. And here you are reading the printed word and learning. A dog or a chimpanzee cannot do any of these things, but man can do all of them.



12 A nerve cell with its long fiber. Each end of the cell also has short fibers to connect to other cells. *Project:* Make a model of a nerve cell. Use an electric cord for the fiber. What could you use for the cell?



13 The brain, showing the job of the cerebrum. If you were a doctor, what part would you suspect might have been injured if a patient had lost his memory? if he could not recognize shapes?

No scientist knows exactly how the nervous system does its work. We do know, however, that the nerves carry impulses to the brain. We know, too, that somehow the brain sends these impulses along so that they go to the right place. Also, you shall see that the brain *interprets* these impulses; that is, it gives them meaning. So the stimulus *football* is interpreted by the brain as something to be kicked, not eaten.

As Fig. 13 shows, we can see that the brain is made up of three parts. The *cerebrum* (SEH-ruh-brum) sits like a cap on the *cerebellum* (ser-uh-BEL-um). And the *medulla* (meh-DUHL-uh) is that long portion which connects the brain with the spinal cord.

We know that the cerebrum has certain parts that do certain work. Scientists have found out about these areas from various experiments with animals, and from studying human beings whose brains have been accidentally injured. For instance, they have discovered that the part for thought, memory, and feeling is found in the front of the cerebrum. The part for hearing is found at the side of the cerebrum, and the part for sight in the back of the cerebrum. Because scientists know the work of each part of the cerebrum, they have been able to make a map to show the parts of the cerebrum which take care of the different things we have been talking about (Fig. 13).

Many experiments have shown that the brain is the center of feeling and understanding. Doctors know that the nerve cells in the brain can be "put to sleep" with ether or other anesthetics. Then the brain does not feel any impulses from the part being operated on. Sometimes the nerve cells near the part of your body being treated may be deadened by novocain, as when your dentist pulls a tooth. What the novocain does is to

prevent the impulses from getting to the brain from the nerve in the tooth.

The cerebellum is the center for making your muscles work as a team. To get your muscles working together in such acts as kicking a football, dancing, writing, or threading a needle, you need your cerebellum.

Your medulla is the center of certain of your most important acts: breathing and heartbeat, on which life itself depends. The medulla also helps to control acts such as swallowing and yawning.

Now you know something about the parts of your body used in learning. You are ready to look at some of the ways in which you learn.

YOUR INBORN WAYS

At the moment you were born, you could do certain things. You could do these things almost perfectly and without practice. Some simple experiments will show you some of the acts you could perform without practice.

Unlearned Acts

Get a piece of glass or cellophane which you can hold before your face. Now ask a friend to throw balls of paper at the glass. Do you blink your eyelids? Try it again. Then try it on your friend, and on others.

Here is another experiment. Stand before a mirror, flashlight in hand. Look into the mirror. Then flash the light at one eye. We predict that the pupil of your eye will become smaller. Try it on other students. Do the pupils of their eyes become smaller?

Without knowing you personally, we know that if you cross your legs and are tapped just below the kneecap, your foot will kick out. Without seeing you, we know that your ribs are moving as you breathe. We also know that your heart is beating. We know you cannot control your heartbeat or stop your breathing.

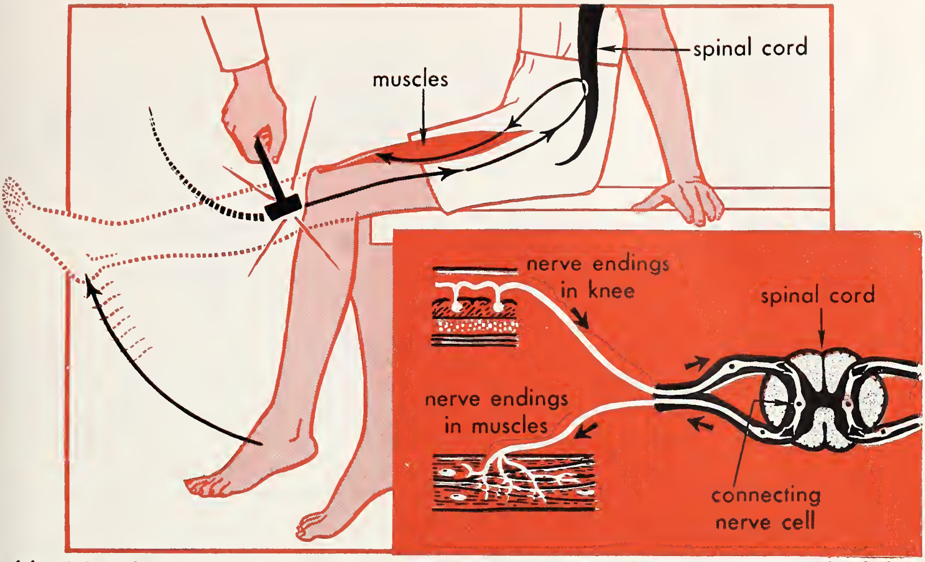
All these acts are *reflex* acts. Like all other responses, reflex acts take place only when there is some stimulus to produce them. Almost all human beings have the same reflexes. They are born with them. A quick movement before the eyes is one stimulus for the blinking response, which is a reflex. Dryness of the eye is another stimulus that causes blinking. There is a stimulus for every reflex act, even for your breathing and for your heartbeat.

Usefulness of Reflex Acts

Try this. What is $8 \times 16 \div 2 \times 4$? You have to think about it. Suppose you had to think about getting your heart to beat, your lungs to breathe, your eyelids to blink, your pupils to become smaller in bright light. Not only that, but suppose you had to think about keeping your heart, lungs, stomach and other organs inside your body working regularly as they do now. Impossible! Of course. Because these acts are reflexes, they are *automatic;* that is, they work without your thinking about them. Reflexes are *inborn automatic* acts. Your heart beats. You breathe.

Explaining the Reflex Act

Let us study one of your reflexes — one so common that ordinarily you don't give it a second thought.



14 Ask a friend to sit at ease on a table. With the edge of your hand strike him below the kneecap. The picture shows what happens. Trace the nerves from below the kneecap to the spinal cord and back to the muscle of the leg, and you will see why his leg kicks out.

Let us examine a common act like your knee reflex (Fig. 14). The stimulus, a tap below the kneecap, sends an impulse along a nerve. This nerve takes the impulse to the spinal cord. From here it is returned to the leg muscle. A diagram of the reflex nerve pathway looks like the one in Fig. 14. You are born with this nerve pathway, just as you are born with other reflex nerve pathways like those for blinking and sneezing.

A reflex act may take place even if the person is under ether and the cerebrum is therefore not acting. Reflex acts do not need thinking, a fact which helps explain a rather peculiar thing. Picture this. You touch a hot iron with your finger. Quickly your arm muscles draw your finger away. *After* you have taken your finger away, you say, "Ouch!" Taking the finger away from a hot object is a reflex act. The impulse goes first to the spinal cord, then right back to the arm muscle. Taking your finger away from the hot object happens, therefore, without thinking. But saying "ouch" needs thought. It is a response you have learned. Since you said "ouch" *after* you pulled your finger away, it shows that your brain did not take part in the act of removing the finger. The "ouch" was a response to the *pain* stimulus which reached the brain after you had pulled your finger away.

However, much remains to be explained. Even though we do not know just what an impulse is, or how thinking is carried on, we know that these acts cannot go on without nerve cells. We know that reflexes are inborn automatic acts. We know that the nerve pathways of these reflexes are present at birth. Once the

stimulus is given, the impulse travels over this pathway and the response occurs.

Sometimes one reply leads to another, so that a given stimulus may set off one reflex which in turn sets off other reflexes. The act of breathing is the result of such a chain of reflexes.

CHANGING INBORN BEHAVIOR

As you might expect, many scientists have been studying learning. If scientists could find out what happens in our nervous systems as we learn, we might know how learning takes place. We would then be a long way on the road toward solving many of the important problems which trouble us. Ivan Pavlov was one of the first to do some important experiments on learning. And this is what you might have seen had you visited him early in this century.

Pavlov's Dogs

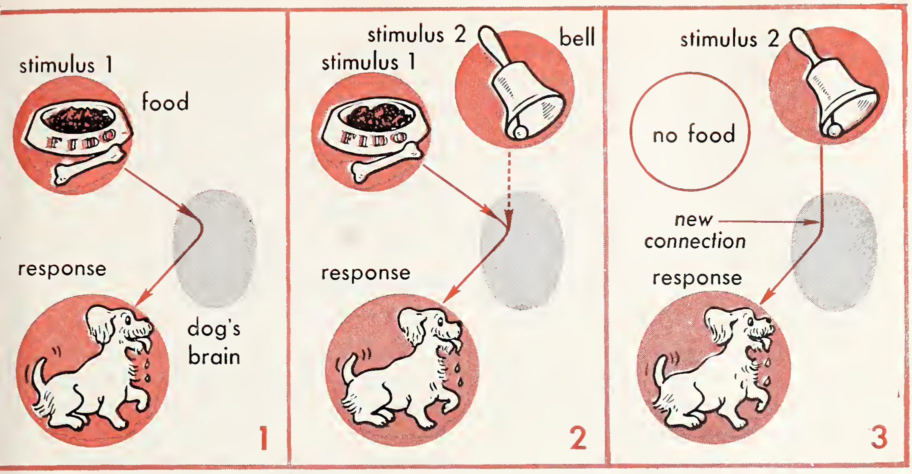
In Ivan Pavlov's laboratory in Russia over 50 years ago, you would have seen a dog acting very strangely. The moment a bell was rung, the dog began to salivate (SAL-iv-ate). (Saliva flowed in his mouth, much as it does in yours when you see or smell a very inviting meal.) He acted just as if he were going to be fed. Usually, a dog's mouth doesn't water when he hears a bell. This response must have been acquired, or learned. In fact, some of Pavlov's dogs would salivate at the sound of a bell, others at the lowering of a white square or a flash of light. How did they get this new behavior?

Pavlov knew that every time a dog saw food he salivated. Pavlov decided to ring a bell as he gave the dog food. In other words, the dog was presented with two stimuli at once, food and the sound of a bell. After a few weeks, when the bell alone was rung the dog responded to the bell as if he were responding to food. He salivated.

New Reflexes

The act of salivation is a reflex. The old stimulus, food, causes an impulse to travel along an inborn nerve pathway. The new, or *substitute*, stimulus, the ringing of the bell, is given at the same time as the old stimulus (Fig. 15). In this way the *new* stimulus is connected with the inborn nerve pathway. For a period of time, the new stimulus is given with the old. So it happens that the two, the old (inborn) and the new (substitute) stimulus, are connected and cause the same response. Finally, the new stimulus alone causes the desired response (Fig. 15). The dog's inherited behavior had been changed. It was as if the animal had acquired a new reflex. Pavlov called this new reflex a *conditioned* reflex.

Notice the part that reward played in forming a conditioned reflex. Each time Pavlov's dog heard the bell, he also got food, which he liked (reward). Pavlov found that after his dogs had learned to salivate on hearing a bell, he could break the conditioned reflex. He did it this way. When the bell was rung, the dog salivated. But he was not given food (his reward). This routine was repeated each time the dog reacted to the bell. After a while, the dog no longer salivated on hearing the bell. His conditioned reflex had been broken.



15 If you have a dog, this diagram shows how you can teach him to respond to the ringing of a bell in the same way he would respond to food. How is the connection made in his brain? Stimulus 1 (the signal) and 2 (the substitute) are given together until he reacts to stimulus 2. *Project:* Train a goldfish or a guppy to come to one corner of its tank when you flash a light.

In much the same way, a dog learns to give a new response to an old stimulus. For instance, hunting dogs on farms sometimes hunt and kill chickens. How would you train the dog to leave chickens alone?

Some farmers, if a dog has killed a chicken, tie it around his neck with wire. Soon the chicken begins to decay and give off a very bad smell. In the dog's nervous system the stimulus "chicken" may be related to the stimulus "bad smell." Or the stimulus "chicken" may have become related to the stimulus "harsh words" given by the dog's master. Thus, the dog learns to leave chickens alone.

Later you will see how a reward or punishment given at the proper time may be of use to you in learning.

Training Your Dog

You can use Pavlov's experiments with conditioned reflexes to teach your dog different kinds of behavior. Suppose you want your dog to learn to sit up. Each time you give him his food or something he likes, say, "Sit up," and make the dog sit up. The stimulus, food, and the sound of the words "sit up" (and the position of his body) will be associated in the nervous system. Soon the dog will sit up when you say, "Sit up." Be sure to reward him when he does this. You should pet him, or give him something he likes. You need not do it each time, but do it often enough so that the learned behavior is fixed.

FORMING HABITS

You get up in the morning. You wash, dress, and tie your shoelaces. You brush your teeth. You use a spoon and fork to eat. You switch on the radio to hear the morning weather

report. You get your books together. These are not inborn acts, or reflexes. These acts depend on nerve pathways developed after you were born.

Do you want proof? Watch your baby brother or sister, or any baby. Can the baby do the simple things we have mentioned above? See how long it takes before the baby learns how to hold a spoon or a toothbrush the right way.

If you had to figure out how to do these things every morning, it might take all day. Good habits, therefore, save time. Such habits make life easier to live. Habits are *learned automatic* acts. They are not reflexes, which are *inborn automatic* acts. By getting new habits, you can change your behavior. Bad habits waste your time and may even make you fail in your work. Good habits improve your behavior and make for success.

New Habits

At first, everyone needs help in forming habits. As we grow up, we are more and more responsible for our own actions. In order to form a habit at your age, you should *first want to form that habit.* Although conditioning (habit formation) may go on whether we know it or not, it is generally agreed that habits are formed most rapidly when there is a desire to form the habit. *Second, you must plan for regular practice of the habit. Third, the satisfaction you get out of it helps fix the habit,* that is, makes the act one you can do without thinking. *Desire,* first; then *practice;* then *satisfaction.*

Let us take an example from your past experience. You saw your friend riding a bicycle. "I wish I could ride one," you said. Good. *You wanted to learn.* That was the first step in forming the habits needed to ride a bicycle. Then do you remember how you *practiced* riding a bicycle? And do you remember the *satisfaction* you got when you took your first long ride by yourself?

Habit Formation and Learning

"That's not forming a habit; that's learning," you say. "I learned to ride the bicycle." Habit formation and learning are very much alike. To learn, and to form new habits as well, is really to get new ways of responding to stimuli. It is worth reviewing the steps in habit formation, for they help you form the habits which will help you to learn better.

1. You should want to learn.
2. You must practice regularly the act you want to learn. This usually means that you should plan your work carefully.
3. Whatever you learn to do well brings satisfaction. This satisfaction in turn makes you want to practice more and more until the habit is fixed.

Do you want to learn how to play basketball, how to dance, how to read well, or ice skate? Then reread the "rules of learning" and put them to work to help you learn.

Getting Rid of Poor Habits

If new ways of acting, or habits, can be learned, they can also be unlearned. You know how quickly you forget something you have learned if you don't use it — or practice it. Of course, you can get back much of your skill if you practice again or review your work. That is true of baseball,

Ping-pong, knitting, reading, speaking, or other learned acts.

Let us suppose you have a poor habit. What is a poor habit? It is something you have learned to do which may make people lose their respect for you, or something which wastes your time, or a habit which may result in poor health.

In order to break a bad habit, you put a good one in its place. To do this, you should:

1. Really want to break the habit.
2. Practice a better activity in its place.

Here again you can see how you are different from other living things. You can change what you do by getting new habits or by breaking old ones. Let us see how the "tantrum" habit can be broken.

Directing Your Emotions

Some boys and girls have the habit of letting their emotions take over when things do not please them. For instance, if some boys or girls do not get something they want, they sulk or shout or cry or refuse to eat or go into a tantrum.

How can the tantrum habit be broken? Here is a girl who goes into a rage whenever she does not get something she wants. She may have a strong desire to break this habit (Step 1, above). She knows that she will not be able to get along with other people or her friends. The habit is probably "left over" from her baby days. What habit can she put in its place? One way she can break this habit is to put in its place the habit of counting to 50 whenever she begins to fly into a rage (Step 2, above).

Do you fight at the drop of a hat? Do you become angry easily? Do you lose your temper? Count up to 50. If that is not enough, count up to 200 if you need to. By that time, the anger felt will usually have passed away. Counting up to 50 helps you to get control of yourself only for the moment. After you have counted and are calm, try to find the reason for your anger. You will probably find that whatever the reason was, the tantrum or anger was not a useful or desirable reaction. We cannot always have what we want.

If you do not get angry quickly, or get tantrums, you will have the respect of your fellows, and, what is more important, you will have your own self-respect. For as you learn to control your behavior, your ability to improve it will increase rapidly.

LEARNING

Sultan was a fine chimpanzee. He was trying to get a banana that was outside his cage beyond his reach. In his cage were two sticks, each one too short to reach the banana. If you had been there, you would have seen that one stick could be fitted into the other. Fitted together, the two sticks would reach the banana.

After some tries to reach the banana with his arms only and then with each stick by itself, Sultan gave up in disgust. He sat down in his cage; he wandered about. Then suddenly he ran to the two sticks, put them together, and reached the banana. He had solved his problem.

Learning About Learning

Why bring Sultan into the picture? Sultan's acts are examples of the way an animal learns to solve a new prob-

lem. A child of five or six might have figured it out very quickly, however.

Sultan, however, is not a human being. The size of his brain in relation to the size of his body is much smaller than yours. You have much more brain material. The chimpanzee's smaller brain limits his ability to solve even simple problems. However, you should not make the mistake of thinking that it is the size of the brain alone which is responsible for man's ability to learn and think. The largest human brain ever measured was that of an idiot.

We do not know just how the brain helps men to learn. We do know that there are certain ways of acting and working that help people when they are faced with a new problem.

One Approach to Solving a New Problem

1. Think of past experiences which are likely to help with the present problem.

2. If necessary, get the advice (experience) of several people you trust. Get all the facts you can which will help you solve your problem.

3. With the advice of others, plan a method of attack on the problem and carry it out.

Study the box on this page. Compare the suggestions for solving a personal problem with the approach of the scientist on p. 27.

Learning to Study

You have an important job. Your job is learning to learn well. The knowledge you have gained about your nervous system can help you improve your learning methods. Let us look here on learning at home; that is, learning by yourself. This is something you will need to do all your life. The successful doctor, businessman, or scientist is studying all the time. He is always meeting problems and forming new pathways in his nervous system. If he did not, others would soon be ahead of him.

We know that a student of your age is a busy person. You have many things you want to do. But the main job is to learn well. Let us look at the steps that will help you save time and get more things done.

Step 1. Defining Your Task. The first thing is to make a clear statement to yourself of the problem to be solved, or the things which need to be done. That is what is meant by "defining the task."

Step 2. Making Your Plan. Once the task is defined you are ready to recall those experiences which you have found useful in the past in solving similar problems. You will probably recall them automatically. Then you will make your plan. "This is the way I will do it," you will say. If it is an English assignment, you will arrange your notes in order, or perhaps make an outline. If it is a science project, you will make an outline and a sketch. If it is an algebra problem, your past experience will suggest a method to use in solving the problem or will send you to a reference in your mathematics text. Whatever your task, you will work out a plan. The best learning grows out of the best planning.

Step 3. Getting the Materials. Once you have a plan, you need to set aside the time and get the materials

16 For you to understand the day's work is important. All other things equal, the boy at the right will do his work better and more quickly than the boy at the left. Which is a picture of you? *Project:* Arrange a place where you can do your best work.

to carry it out. Experience has shown that students who set aside a regular time for study — let us say from 4 to 6 or from 7 to 9 each day — finish their tasks. Some students may need more time, others less. But whatever time you choose, be sure to have the materials you need on hand before you start.

Your place of work should be near your reference books. You should have writing materials, ink, sharpened pencils, blotter, ruler at hand. Why? You may be able to rewrite a sloppy paper, but you will never be able to make up the time lost because you have to search for paper or pen. You will take more time to do your job if you have to get up each time you need your study materials.

Is your place of study like the one shown on the right in Fig. 16?

Step 4. Looking to Your Surroundings. Do Experiment 4 in the activities on p. 50. Boys and girls almost always feel certain that television or radio does not bother them when they are studying. But is it really so? Try the experiment and see for yourself. We think you will find that to learn most quickly and thoroughly you need a quiet place in which to study. The best studying goes on when you are responding to one stimulus, not several.

As you read this, are you listening to your radio? looking at your television set? talking to your friends?

Reading Well

If you can learn to get the main ideas from a paragraph or chapter, your studying will mean much more to you. Many students do their assignments but find that they cannot remember much of what they read. Here is a method that will prove useful to you if you have this difficulty.

When you finish a paragraph, put its main idea in one short sentence. Then write this sentence in your notebook, which should always be at your side. Try this. Prove it to yourself. Read the paragraph on p. 14 that begins with "Man, as you now know . . ." and write its main idea in one sentence. You were able to do it, weren't you? Did it make the meaning of the paragraph clearer to you?

You have heard people say of a person, "He reads well and gets everything from what he reads." Such a person can put his reading into clear sentences. Thus his reports in class are clear and to the point. He can get the thought of each paragraph. He does not try to memorize each sentence; rather he puts the main idea into his own words. His cerebrum is at work.

LEARNING WELL

Once you have the habit of good study, you will be able to learn as well as you want to. You will get a habit important to your success.

William James, the great psychologist, concluded his famous essay on the way habits were formed with the following paragraph:

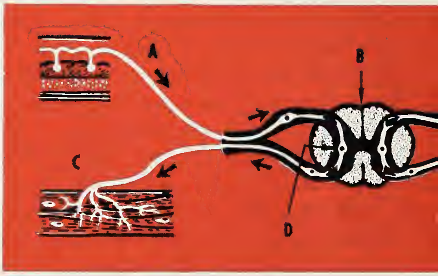
> Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he keeps faithfully busy each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out.

The *competent person* is the one who has been able to change his behavior along lines which bring success. Man's ability to change his own behavior through learning is his most important trait. Upon it depend man's future and your future.

You, Your Learning, and Science

What has all this to do with science? You now know that modern man has special physical traits that set him apart from other living things. One of these is his brain. With its help he thinks, imagines, invents tools. Without this ability to use his brain to control his environment, man would be at the mercy of animals stronger, faster, or better protected than he is. You have an idea of how man learns.

One hundred years ago there was no radio, no television, no automobile, no airplane. There were few big factories, no fine hospitals. But we have all these today. You and others like you have inherited a world in which there is still work to be done. Your brain, your organs of speech, and your hands are the tools with which you and some two billion human beings like you can build a successful and happy life on this earth.



LOOKING BACK

Tool Words

To be sure you understand the key words below, write the statements in your notebook and replace each blank with the correct word from the word list. DO NOT MARK THIS BOOK.

nerve fibers	reflexes	stimulus
nerve cell	medulla	response
nerves	impulse	brain
cerebrum	habit	spinal cord
cerebellum	conditioning	

1. Man can invent because of his . . . . At birth, man has a set of inborn acts, called . . . . Later, as he learns, he develops . . . . Inborn acts can be changed by . . . .
2. Each act starts with a . . . to which there is a response. The impulse is carried along . . . .
3. If we look into the brain of a frog we find it is made up of three parts found also in man, the . . . , . . . , and . . . . Without his . . . , man could not think.

Test Yourself

1. In each of the following groups of terms is one term which is not related to the others. Copy that term in your notebook and state why it is not related, and why the others are related. DO NOT MARK THIS BOOK.
   a. cerebrum, cerebellum, medulla, spinal cord
   b. habit, learning, reflex, conditioning
   c. dancing, writing, heart beat, speaking
   d. stimulus, memory, nerve pathway, response
2. The diagram on the opposite page is of a reflex act. Copy the diagram in your notebook. Label the diagram and give the use of the parts marked by each letter.

GOING FURTHER

In the Laboratory

1. *Experimenting with animal behavior.* If you have a bottle of fruit flies in your school laboratory, you may discover their responses to certain stimuli. Shake the bottle of flies into a large glass bottle. Quickly plug it with cotton or cork. In which direction do the flies travel? Turn the bottle upside down. In which direction do the flies travel now?

Turn the bottle with one end toward the window. In which direction do the flies travel? What can you say about the responses of fruit flies to the different stimuli?

2. *Experimenting with conditioning.* Can you get a goldfish to rise to the corner of an aquarium just by putting your hand over the corner? (Hint: A goldfish will rise to snap at fish food — the original stimulus.)

3. *Experimenting with habit formation.* Dictate a few sentences of a paragraph on p. 48 to your classmates. Ask them to write it as you dictate. Time them. Now ask them to write it from dictation again, but this time omit crossing their *t*'s or dotting their *i*'s. Give them the same amount of time used before. How many can complete their writing in the time allowed? Why?

4. *Experimenting with learning*

a. Memorize the first stanza of the poem below with the radio or television set on, or stay in the room where the rest of your family are talking. Time yourself. Memorize the second stanza in a quiet room. Time yourself. Which took longer? Why?

Flee from the crowd and dwell with truthfulness;
Suffice thee with thy goods, though they be small;
To hoard brings hate, to climb brings giddiness;
The crowd has envy, and success blinds all;
Desire no more than to thy lot may fall;
Work well thyself to counsel others clear,
And Truth shall make thee free, there is no fear!

Torment thee not all crooked to redress,
Nor put thy trust in fortune's turning ball;
Great peace is found in little busy-ness;
And war but kicks against a sharpened awl;
Strive not, thou earthen pot, to break the wall;
Subdue thyself, and others thee shall hear;
And Truth shall make thee free, there is no fear!

— Geoffrey Chaucer, "Ballade of Good Counsel" [1]

b. Memorize the three lists of words below. Time yourself. Which list took longest? A half-hour later try to repeat each list in order. Which list do you remember longest? Why?

certain	gewiss	naitrec
born	geboren	nobr
science	Wissenschaft	niecsec
Joseph	Seppel	Sephoj
always	immer	swayla
never	niemals	revne
heaven	Himmel	nevhea

5. *Experimenting with plant behavior.* Have you ever made a pocket garden? Take some radish seeds and soak them in water for 24 hours. Now take two small square pieces of glass about the size of a lantern slide and place two pieces of blotter (about the same size as the glass) between them. Space the radish seeds about a half-inch apart on the blotter. Now you have a blotter with radish seeds sandwiched between two pieces of glass. Keep the glass plates together by means of a rubber band. Keep the blotter moistened with water. After a few days the seeds will grow stems and roots. Keep the glass plates standing on one edge. In which direction do the roots grow? Turn the glass plates on another edge. Now what happens to the roots and stems?

6. Take a geranium or a similar plant and place it near a window. What happens to the leaves within 48 hours? Why?

[1] Modern version from *The Poems of Henry van Dyke*, published by Charles Scribner's Sons.

Put on Your Thinking Cap

1. "He was born dishonest," said Mr. Doe. Now that you have learned something of the way living things behave, how would you convince Mr. Doe that dishonesty is not inborn?

2. "You can't teach an old dog new tricks" is a common saying. Is it true? How would you go about teaching an old dog a new trick? (See p. 43.)

3. Can a plant learn? Explain.

Adding to Your Library

These booklets, published by Science Research Associates, 57 West Grand Avenue, Chicago 10, Ill., may be useful:

1. *How to Be a Better Student* by J. Wayne Wrightstone, 1956.

2. *Your Abilities* by Virginia Bailard, 1957.

3. *Improve Your Learning Ability* by Harry N. Rivlin, 1955.

4. *Making the Most of Your Intelligence* by Lyle M. Spencer and Ruth Dunbar, 1956.

5. *How to Get into College and Stay There*, 1958.

You may also find the following helpful:

6. *Mind Your Manners* by Betty Allen and Mitchell P. Briggs, Lippincott, Philadelphia, 1957. A teen-age guide to proper etiquette.

7. *Scholarships, Fellowships, and Loans* by S. Norman Feingold, Bellman Publishing Co., Box 172, Cambridge 38, Mass., 1956.

If you want to learn more about the way the nervous system works, read *Exploring Biology* (5th edition): *The Story of Living Things* by E. T. Smith, Harcourt, Brace, 1959.

A Bit of Research

1. Do rats learn? Plan an experiment to see whether a rat learns. What you will need is a textbook on psychology. Almost any college textbook published after 1945 will do. There you will learn about experiments in learning, especially on rats.

2. Very little is known about the way people imagine. But you can do a bit of "research"; imagine "white grass" and "blue apples," much as the boy below is imagining a white elephant. What seems to happen in your brain as you imagine?

Careers for You

Is psychology for you? *Psychologists* are scientists who study the behavior of animals as well as of human beings. Your librarian and teacher will help you decide. So will reading *I Find My Vocation* by H. D. Kitson, McGraw, 1947, or *Careers and Opportunities in Science* by Philip Pollack, Dutton, 1954.

Is teaching for you? *Teachers* are practical psychologists who try to help young people grow up and solve their problems. Ask your teacher about opportunities in teaching.

17 The wonder of imagination. Close your eyes and imagine a white elephant. Then imagine a white tree. Your imagination helps you invent.

UNIT 2

Lengthening Man's Life

Dr. Joseph Lister, an English surgeon, had read of experiments performed less than one hundred years ago by Louis Pasteur in France and Robert Koch in Germany. These experiments had shown that some diseases were caused by germs. Dr. Lister ordered the doctors in his hospital to sterilize their hands, their instruments, and anything that might carry germs to the patient. Not long afterward the death rate dropped. Today the discoveries of Pasteur, Koch, and Lister are rigorously applied in modern hospitals.

For a boy or girl born only a hundred years ago, the average life span was about 45 years. Scientists now tell us that a boy or girl — *you* — born in the United States between 1946 and 1960 will live to an average age of nearly 70 years. *This gift of 25 years is yours.* But to realize this gift you need to start now to understand the systems of your body and how they work together. You then have a better chance to reach this *average* age — or go beyond it.

Your Science Inventory

How much do you already know about the lengthening of man's life? Copy these questions in your notebook and write your best answer for each one. When you have finished this unit, check your answers.

1 If I look through a microscope at one of my cheek cells stained with iodine, the part that will be darkest in color is (a) the cell membrane, (b) the cytoplasm, (c) the nucleus, (d) all the protoplasm.

2 The kind of tissue that causes my ear to keep its shape is (a) bone, (b) cartilage, (c) muscle, (d) skin.

3 New red blood cells are made in the (a) bones, (b) cartilage, (c) fat, (d) muscles.

4 Limewater turns milky when I breathe into it because my cells give off (a) carbon dioxide, (b) nitrogen, (c) oxygen, (d) water.

5 To find out how many calories a food contains, I would have to (a) boil it, (b) burn it, (c) eat it, (d) freeze it.

6 If I drink enough orange or tomato juice, I will be sure *not* to have (a) scarlet fever, (b) diabetes, (c) rickets, (d) scurvy.

7 My skin can make vitamin (a) A, (b) B, (c) C, (d) D.

8 If you throw away the water in which you cook vegetables, you waste money and (a) vitamin A, (b) vitamins B and C, (c) protein, (d) roughage.

9 A cell which does *not* have a nucleus is a (a) cartilage cell, (b) fat cell, (c) red blood cell, (d) white blood cell.

10 A cracker which turns red when boiled in Benedict's solution must contain (a) fat, (b) protein, (c) sugar, (d) vitamins.

11 Bile is made in the (a) intestine, (b) liver, (c) pancreas, (d) stomach.

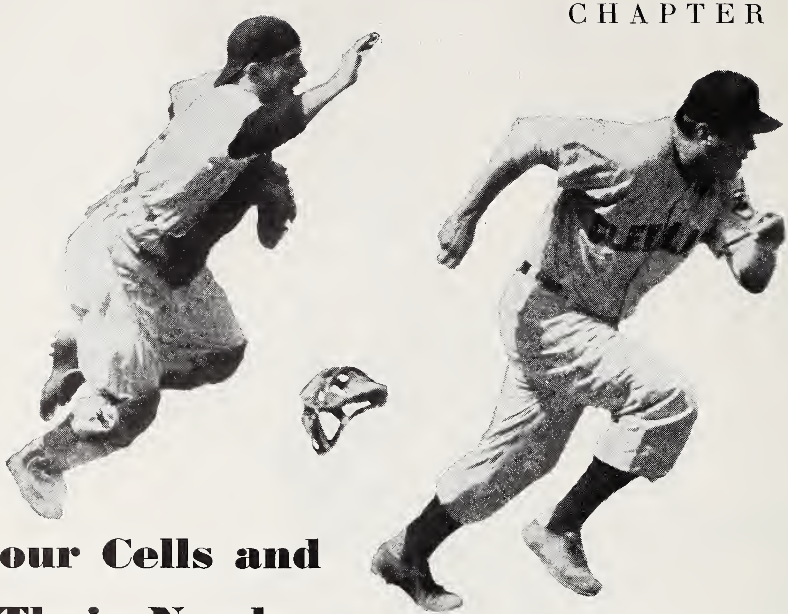
12 Most bacteria cause (a) disease in lower animals, (b) disease in people, (c) disease in plants, (d) no disease.

13 The antiobiotic penicillin comes from a (a) blue mold, (b) white mold, (c) black mold, (d) gray mold.

14 We do *not* know the cause of (a) smallpox, (b) cancer, (c) polio, (d) tuberculosis.

15 All the following are defenses against bacteria, except: (a) antibodies, (b) filtration, (c) skin, (d) toxins.

CHAPTER 3



Your Cells and Their Needs

Speed and action. Legs churning, body straining — two fine athletes. This could not be without cells working together, as they are right now in your body. Healthy cells mean a healthy body and long life.

THINK of the best baseball team you have ever watched. What makes this team win so many games? Is it good pitching? Is it good outfielding? Or is it the high batting averages of some of the players? If you stop to think, you will realize that neither good pitching, good fielding, nor good batting alone could win baseball games. Of course, a good team needs good players. But after all, isn't it the smooth teamwork of all these players working together that brings in the runs? Next time you go to a ball game, watch the smooth teamwork. Baseball takes good organization. That is, each player has his own position to play, and all the players work as a team and follow the rules.

Your body is something like a well-trained ball team. The cells in your body are the players, each cell doing its own part but also working with other kinds of cells to keep your body running smoothly. Your health depends upon how well all your cells can do their work. When injury or disease strikes, you find that you cannot work or play as well as you should. Then your cells need repairs or re-

placement, and you may need to call the doctor.

Scientists know that cells are important. They spend much time studying them because they know that every living thing is made of cells. A cell is the smallest unit of living matter. For the moment, you may think of it as a building block of living things, as a brick is a building block of a brick building.

CELLS EVERYWHERE

Let us look at some of your cells.[1]

With a toothpick gently scrape the inside of your cheek. Put the scrapings in a drop of water and add a drop of iodine. When the slide is placed under the microscope, you will see cells like the skin cells in Fig. 18.

Each of these cells has its *nucleus*, a small beadlike part of the cell, near the center (Fig. 18). The nucleus is surrounded by *cytoplasm* (SY-toh-plazm), the part of the cell outside the nucleus. The entire cell is surrounded by a *cell membrane*. Study Fig. 18 and see if you can find the different parts of the cell.

The entire cell — all its parts, nucleus, cytoplasm, and cell membrane — is made up of a substance called *protoplasm*. Protoplasm is the living material of which all cells are made.

Scrape the inside of your cheek again and make another slide. No matter where you scrape your cheek you get the same kind of cells. They cover the inside of your cheek like a flat sheet. Their work is to cover and protect the muscle and nerve cells underneath.

[1] You will need a microscope, some glass slides, water, a medicine dropper, and some stains such as 1% iodine in alcohol.

Any group of cells (like your cheek cells) which work together doing one kind of work form a *tissue*. In your body there are groups of bone cells forming bone tissue, muscle cells forming muscle tissue, and nerve cells forming nerve tissue (Fig. 18). These cells of your body are harder to examine than are the cells protecting the inside of your cheek. But you can examine cells of other animals.

In the frog's intestine you will find muscle cells which look like those in Fig. 18. They are long and slender muscle fibers. Each muscle cell can shorten and lengthen as needed, whenever the muscle is doing its work. Your muscle cells act in the same way as those of other living things.

The cells of nerve tissue are long cells, in fact, the longest cells in the body (Fig. 18). Nerve tissue keeps the different parts of your body in touch with your brain. The brain itself is made up largely of nerve tissue.

Cells of still different shapes form the tissues that make up the bones, the cartilage (gristle), and the tendons[1] in your body (Fig. 18). Your teacher may have some slides showing different kinds of cells.

In your body, then, you will find cells grouped in the following tissues:

1. *Cells which cover and protect.* These cells cover the inner and outer surface of your body, such as the cells of your cheek and skin. The cells which line your intestines, your lungs, and your blood vessels are grouped with the protective cells of the body.

[1] Tendons are the tough fiber-like tissues which join muscles to bones.

2. *Cells which help you move.* Muscle cells do their work by getting longer and then getting shorter.

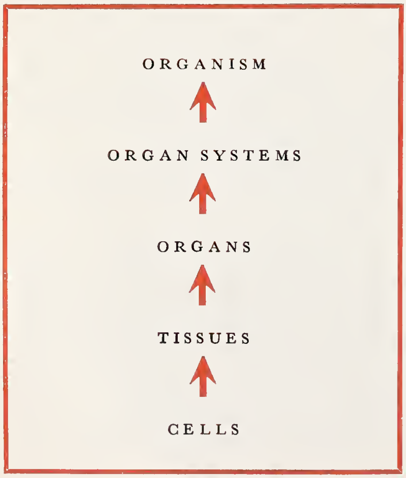
3. *Cells which keep your body tissues working together.* Nerve cells have connections with all parts of the body.

4. *Cells which support the parts of the body.* Supporting cells make up cartilage, bones, and tendons.

5. *Cells in your blood.* Every cell in your body needs oxygen. Your red blood cells take up oxygen and carry it to all parts of the body. Your white blood cells, as you will see later, fight disease by killing germs which enter your body.

Tissues Make Up Organs

Just as cells in your body are grouped together to form covering, muscle, nerve, and supporting tissues, so tissues are grouped together to form *organs*. Each organ in your body has a special use. For instance, your eyes and ears are sense organs for seeing and hearing. Your lungs are organs for breathing. Your stomach is an organ for digestion. Each organ has in it the different kinds of tissue cells.



Organs Make Up Organ Systems

Each part of your body works with other parts to carry on the necessary work. The cell, as you have just read, is the smallest living unit in the body. These cells make up tissues. Tissues make up organs, and organs may work together in a system. The digestive system is a group of organs that work together (mouth, gullet, stomach, and intestines). The circulatory system is another group of organs. What organs would make up the circulatory system?

Organ systems make up the entire body, which we call an *organism*. A living thing made up of its parts is an organism. Every living thing is an organism. You are an organism.

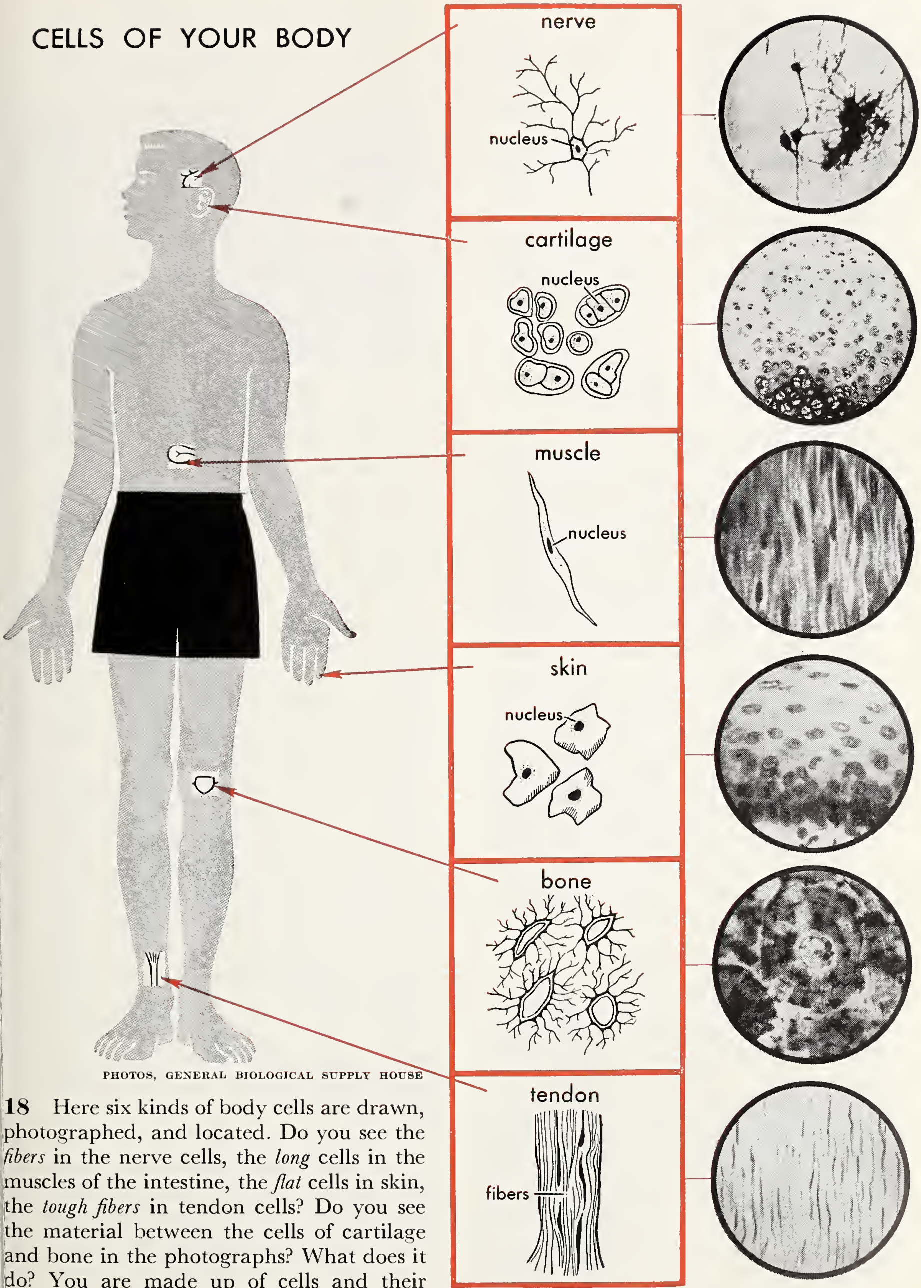
CELLS AS BUILDERS

It is the cell, then, which is the building block of your body. You are growing rapidly now. Your cells make things that are useful to you.

Products of Cells

Certain cells in your body make materials which form bone and teeth. Bone is hard and is made for support. Flip the top of your ear with your finger. You can bend the ear, yet it keeps its shape because of the cartilage in it. Cartilage can bend, yet it is stiff enough to keep its shape. The next time you have meat for dinner ask your mother to save you a piece of the gristle to examine. Gristle is fairly hard cartilage.

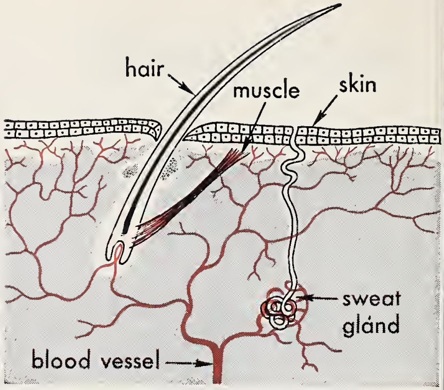
CELLS OF YOUR BODY



PHOTOS, GENERAL BIOLOGICAL SUPPLY HOUSE

18 Here six kinds of body cells are drawn, photographed, and located. Do you see the *fibers* in the nerve cells, the *long* cells in the muscles of the intestine, the *flat* cells in skin, the *tough fibers* in tendon cells? Do you see the material between the cells of cartilage and bone in the photographs? What does it do? You are made up of cells and their products.

Your nails and hair are formed from cells. No one really knows how long nails can grow, but the cells at the base of your nails are constantly forming more nail. Newly made cells keep pushing the nail forward. Your hair grows, also, by forming more cells. Cells push upward from the root of the hair in the skin. These cells join together and harden into hair. As long as the cells are alive, new hair will grow (Fig. 19).



19 Your skin in cross section. Do you see the muscle which can pull at the hairs of your skin? And the sweat gland which sends wastes out through the pores?

Replacing Lost Cells

Does your skin peel when you sunburn? Have you had a cut or a burn recently? New cells are made to replace those that were destroyed. Cells on the surface of the skin are always dying and wearing out. You certainly rubbed some away when you washed this morning. These cells had been replaced before you rubbed the worn-out ones away.

One-third of your red blood cells will wear out and die within the next four months, as they will in every human being. These cells, too, must be replaced; otherwise not enough oxygen will be brought to your body cells. New red blood cells are made in the red marrow of your bones.

Cells, and the Burning Within Them

Your body, with all its tissues and organs, works for you all the time. If you are to carry on your daily activities, your body must have energy.[1] For instance, you must have energy for moving your arms and legs. You must have heat energy to keep your body warm. Can we measure this energy in any way? Perhaps we can compare a living thing that is growing with one that is not.

Let us take some dried beans and divide them into equal parts by weight. The dried beans are alive. Proof? Plant a few and from them come living plants. The dried beans are just in a resting stage.

The cells in the seed start to grow when water is added. Soak one-half of the bean seeds overnight and keep the other half dry and inactive. How can we measure the energy output, if there is any? We can measure heat energy given off by the soaked seeds by placing them in one Thermos bottle. Place the dry ones in another. Fit each Thermos bottle with a one-hole rubber stopper and put a thermometer in each stopper (Fig. 20).

The bottle with the soaked seeds in it shows a higher temperature. Why? Heat energy is being given off by the soaked seeds because they are starting to grow. But no heat energy

[1] Scientists define energy as the ability to do work.

is being given off by the dry seeds. All their cells are inactive. After a few days young plants will sprout from the soaked seeds. The dry seeds do not sprout. When cells are active, energy is one result. One form of energy of active cells is heat energy.

Cells and Their Energy

One way to get energy is to burn coal. The carbon in the coal unites with the oxygen in the air. Then the coal burns with a flame. In the cells of your body, something like this happens, except that food instead of coal is burned. Because the burning of food in the cells is slow, there is no flame. Energy, such as heat energy and energy for growth, is the result of this slow burning. This slow burning is called *slow oxidation* (oks-ih-DAY-shun). Oxidation, as you may remember, is the combining of a substance with oxygen.

Let us burn a substance like a small amount of fat (butter will do) in a jar. You can make a butter candle by putting some butter around a string. We find that oxygen is needed, because if we cover the jar the flame goes out. The heat of the flame is the energy given off. When we add limewater to the air in which the fat has burned, we find that the limewater turns milky. Limewater turns milky in the presence of carbon dioxide. Therefore, we know that carbon dioxide has been given off. On the square of glass that covered the jar in which we burned the fat, we find droplets of water. Therefore, in addition to carbon dioxide, water is also given off. Thus water, carbon dioxide, and energy are all given off when a substance is burned.

The same thing happens when sugar is burned (oxidized) in your body. Carbon dioxide and water are given off. And energy is also a result of this oxidation, as it is in the burning of fat.

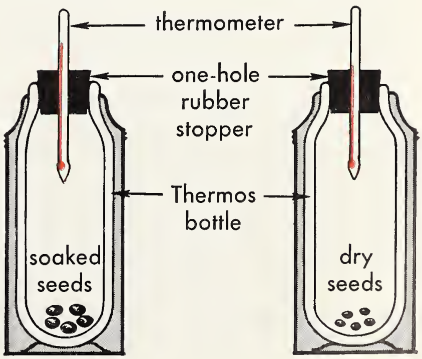
Every person burns, or oxidizes, his food at a different speed. This speed can be measured by a *metabolism test.* A metabolism test is a test of how fast oxidation is going on in a person while he is at rest. The test is taken when the person is lying quietly, several hours after he has eaten. A metabolism test measures the heat energy given off by the cells of the body.

Burning in Your Body Cells—A Test

You can show that your cells are oxidizing, or burning food, now.

First, put a thermometer into your mouth. After leaving it there for two minutes you will find it

20 Compare the red lines showing the temperature in the two thermometers. Why is it higher for the Thermos bottle at the left than for the one at the right? Do this experiment with beans, squash, radish, and other seeds. Fill your Thermos bottles at least ¼ full of seeds.



probably reads 98.6° F. Your body must be giving off heat. When your temperature is higher or lower than 98.6° F., your cells are not working as they should.

Second, blow your breath through a straw into limewater. Since the limewater turns milky, your body is giving off carbon dioxide (CO_2). Carbon dioxide is the waste product given off during oxidation (Fig. 21).

Third, go over to a mirror and breathe on it. You can see that you are giving off water.

Perhaps these tests do not really prove to you that you are oxidizing food. How do you know that you are not breathing in as much carbon dioxide or water as you are breathing out?

Testing the Air, In Your Body and Out

If we could test the air that comes into the body and the air that leaves it, we would have proof that air is changed as it passes through the body. When you breathe in, we say you *inhale* air. When air leaves the lungs, we say you *exhale* air.

With the simple apparatus shown in Fig. 21, you can inhale air through the water in one bottle and exhale it through the water in the other bottle.

Now put some limewater into both bottles; then put the breathing tube into your mouth. Now, inhale through one bottle and exhale through the other. The limewater in the bottle through which you exhale air should turn milky because there is much carbon dioxide in exhaled air. The limewater in the other bottle will remain clear. Exhaled air contains almost 4% carbon dioxide. This carbon dioxide comes from the burning of food in your cells.

Use the same apparatus as in Fig. 21. Dry both bottles. Place them in ice. Now breathe in and out for a few minutes. You will find that the bottle through which you exhale will get misty on the inside. Where did the mist (made up of water) come from? The water in the bottle came from the water vapor in your breath. It has been found that we breathe out about one-third of a quart of water a day from our lungs.

We can show what happens when food is oxidized in the cells by writing it this way:

$$\text{oxygen} + \text{food} \rightarrow \begin{matrix}\text{carbon}\\\text{dioxide}\end{matrix} + \text{water} + \text{energy}$$

Scientists have found that a simple sugar, called glucose, is oxidized in the body. When sugar is being oxidized, the chemist writes:

$$\text{oxygen} + \text{sugar} \rightarrow \begin{matrix}\text{carbon}\\\text{dioxide}\end{matrix} + \text{water} + \text{energy}$$

Sugar, especially glucose, is a basic substance used in the body.

One scientist has said that "sugar is to the body, as coal is to the steam engine, or oil is to the furnace, or gasoline is to the motor." You eat every day to get enough glucose for energy for your work, play, and growth. But you can't live on just sugar. Believe it or not, you would soon starve on a diet of sugar alone. Your body cells need more than sugar in order to be healthy. Let us see what else you need to keep your cells in action. What other foods do you

need to keep oxidation going on in your cells? Let us look at what you ate yesterday. List the things you ate yesterday before you read the next section.

THE FOOD YOU EAT

Of the five lunches listed below, which do you think is the best for good growth and good health?

John's lunch: Bread, spaghetti with tomato sauce, potatoes, cake

Helen's lunch: Jelly sandwich, bottle of pop

Joe's lunch: Soup and a glass of milk

Tom's lunch: A roast beef sandwich, green salad, milk, an apple, bread and butter

Betty's lunch: An ice cream soda and a bar of chocolate

Only Tom's lunch is truly a good lunch. His lunch builds good bone, muscle, and nerves. It gives him the energy he needs to do his work. It is also tasty and satisfies his hunger. Did your lunch today do these things for you? Perhaps you need to know more about foods and how to choose those that are best for you, if you wish to be strong and healthy.

If you were asked, "Why do you eat?" you might answer, "I eat because I am hungry," or "I eat to keep strong and healthy." These answers are partly true, but do you know all that foods can do for you?

The right foods give your body materials for:

1. Growth, that is, increase in height and weight
2. Energy for work and play
3. Repair of muscle and other cells in the body
4. Smooth working of all the organs of the body

DAVID B. EISENDRATH, JR.

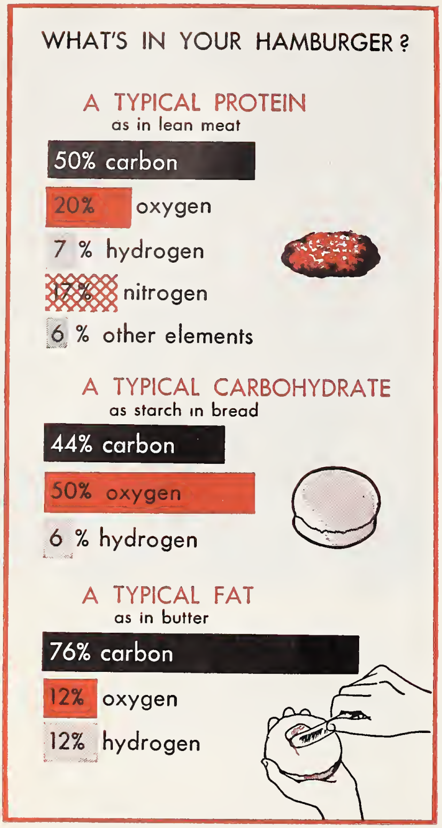
21 By breathing air in from one flask and breathing it out through the other, this student is demonstrating that the lungs exhale more carbon dioxide than they inhale. Do you know why?

Food is any substance you eat that will give you what you need for *growth*, for *energy*, for *repair of tissues*, and for *smooth working of the body.* Which foods should you eat to provide for these four needs? Your health depends on the foods you choose.

What Is in Food?

Suppose we were to examine some of the common foods you eat to see what different kinds of substances are found in them. All foods can be broken down into a few basic substances. Chemists call these substances *nutrients* (NOO-tree-entz). There are six nutrients:

1. *Carbohydrates* (like sugars and starches)



22 What's in your hamburger? Carefully study the table above and see. How does a typical protein differ from a typical carbohydrate?

2. *Proteins* (like those in egg white and meats)
3. *Fats* (like those in butter, oil, and fat meat)
4. *Minerals* (like salt and iron)
5. *Vitamins*
6. *Water*

Every food is made up of some of these nutrients. For instance, milk has all six of them. That is why it is such a good food.

On pp. 76 and 77 you will find tables listing foods and the amounts of the different nutrients in them. Turn to the list to find out how many kinds of nutrients Tom got in his lunch.

What was missing in Joe's lunch? What nutrients were in your own lunch? To get the different nutrients in your lunch, you need to plan your diet. As a first step, study the tables on pp. 76 and 77. Can you see how people who plan diets carefully would use this table?

What Is in the Nutrients?

You know that you are surrounded by air. You know that air has in it such substances as oxygen and nitrogen. Substances such as oxygen and nitrogen are known as elements. For the moment, all you need to know is that there are 92 elements which are found in nature. (Scientists have made ten others.) Some are known to you — copper, gold, oxygen, nitrogen, carbon (in coal), silver, sulfur, and others. Right now it is enough to know that all materials are made up of elements.

Nutrients, then, are made up of elements. These elements are put together in such different ways that they form different nutrients. Here are a few examples.

Sugars and starches, the *carbohydrates*, are made up of carbon, hydrogen, and oxygen. *Fats* also have these same elements, but they have less oxygen than the carbohydrates do. *Proteins* have nitrogen in addition to carbon, hydrogen, and oxygen. The proteins may also have phosphorus and sulfur. *Water* is made up of hydrogen and oxygen.

You can see that the foods you eat are made up of different chemical elements. The storehouses for all

these elements are the soil, water, and the air (Unit 6, Chapter 19). Plants and animals take these elements and turn them into food.

The amount of each nutrient is different in different foods. A food chemist can tell you what nutrients a food has in it and how much there is in any kind of food.

There are simple tests for nutrients. You can learn how to test foods for starch, sugar, fat, and protein. See "Going Further" at the end of this chapter.

Eating for Energy

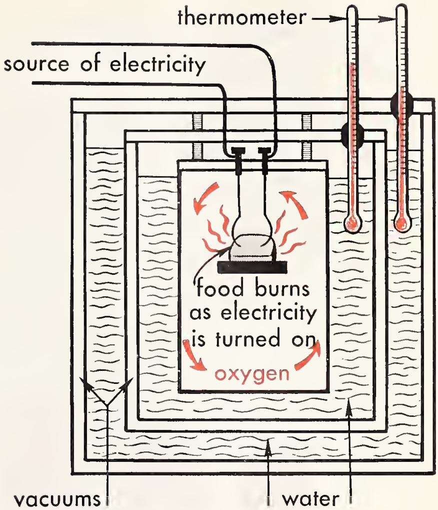
Do you know that it takes energy even to wink your eye or to lift your hand? How much more energy, then, must it take to ride a bicycle or to play ball! One of the reasons why you eat is to get enough energy for your work and play.

Scientists have found that we need different amounts of energy foods, depending on our age and what we do. In order to find out how much energy food each person needs, scientists had to find a way to measure the amount of energy stored in foods. They measured the chemical energy stored in foods by changing it into heat energy.

Heat energy is measured in units called *calories*, just as length is measured in feet and inches (Fig. 23). The unit of heat energy used in food measurement is the *large calorie*.[1]

Scientists have found that a large pat of butter has about 75 calories, an ordinary bar of chocolate 250, a cup of milk about 125, an apple about 100, and a slice of white bread about 60 calories.

On p. 76 is a table which will give you an idea of the calories in the different foods you eat. Use this table to discover about how many calories you have had in your food today.



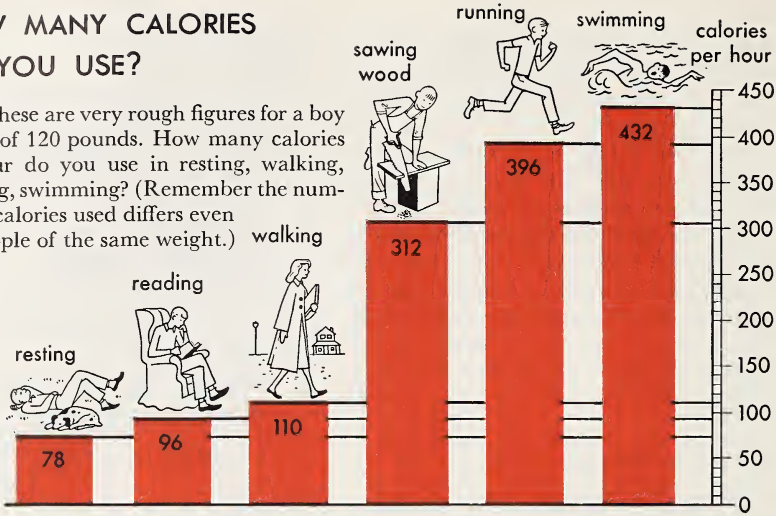
23 A calorimeter is used to find the number of calories in a food. The burning of a fixed amount of food heats the water to the temperature shown on the thermometer on the left. The one on the right does not change because of the vacuums. By measuring the difference in temperature between the two thermometers, scientists can figure the number of calories in a food.

How Many Calories Do You Need?

Even if you knew the number of calories in the kinds of food, the information would be useless in planning your meals. You would still have to know how many calories you need. A person who is very active uses more energy and, therefore,

[1] A large calorie is the amount of heat needed to raise the temperature of 1,000 cubic centimeters of water (about a quart) 1° C. In this book we use the term *calorie* to mean large calorie, to follow most popular books on nutrition.

HOW MANY CALORIES DO YOU USE?



24 These are very rough figures for a boy or girl of 120 pounds. How many calories an hour do you use in resting, walking, running, swimming? (Remember the number of calories used differs even for people of the same weight.)

needs more calories than a person who is not active. You use more calories dancing or playing tennis than you do while reading. A farmer needs more calories than a clerk who works at a desk.

Let us suppose you weigh 120 pounds. You will need 78 calories an hour for sleeping or just lying still. Each hour you will need about:

- 90–100 calories for just sitting or reading
- 95–105 for writing
- 100–120 for typewriting
- 100–150 for walking
- 450–900 for heavy exercise

Knowing these facts, you can figure out how many calories you will need on any particular day. But first, you should make a list of the day's activities and of the time you plan to spend doing each one.

Here is another way to figure roughly how many calories you will need. Young people need about 25 calories per day for each pound of body weight. If you weigh 100 pounds, you will need about 100 × 25 or 2,500 calories per day.

The National Council on Food and Nutrition has found that boys in the first year of high school take in, on an average, 3,500 to 3,800 calories per day. Girls, on the other hand, take less, 2,400 to 2,800 calories per day. Most girls are less active than boys.

However, many boys and girls take in many more calories than they need. A bar of chocolate alone gives you 250 calories, an ice cream soda as much as 300.

How much energy is there in 2,500 calories? Enough to give a boy or girl weighing 100 pounds enough energy to climb 75,000 stairs, each a foot high! Another idea is pictured for you in Fig. 24. How many calories do you need for running? for swimming? for walking? for resting?

Counting Calories

Which are the best foods for energy? Carbohydrates, such as sugar

and starch, are the cheapest energy foods and the easiest for the body to use. Athletes, mountain climbers, and other very active people know that a chocolate bar, or just plain sugar, is a source of quick energy.

Fats furnish energy, too; and fats can be stored in the body. But the body cannot use fats as well as it can use sugars or starches.

Proteins, too, can supply energy, but the main use of proteins is in growth and repair of the body. Proteins help build muscle, blood, and other tissues. They are the only nutrients which have in them large amounts of nitrogen, which the body must have for building new cells.

A normal daily diet for an active boy should have in it about one pound of carbohydrates, one-quarter pound of protein and one-quarter pound of fats. This, does not mean that every day's diet must have these amounts. But a week's diet should take care of these average needs.

Study the table on p. 76. Notice that you can get carbohydrates from fruits and vegetables as well as from cake and ice cream. You will see, too, that such vegetables as peas and beans supply protein, so that you do not need to depend entirely upon meat for your protein. Make a list of five of the best sources of protein in foods.

Scientists have found that there are several kinds of proteins and that the body is in best health when it has a supply of all of them. In an experiment with mice, Dr. G. Howland Hopkins found that, when the mice's diet had corn protein as their only protein, they died in 17 days. But when he added other kinds of protein, the mice lived. Your body also needs different proteins. Your body will get them if you eat fresh vegetables, fruits, eggs, milk, and meat.

Did you get different proteins in your diet today? Examine the table on p. 76. Are you getting enough protein and fat? Are you getting too much carbohydrate?

One would think that getting enough carbohydrates, fats, and proteins would make a healthy body, but that is not true. It has been found that rats fed only these three nutrients become ill and die. Even though the amount of food is enough, they can still starve to death. Let us see how such a thing could happen.

STARVING ON THREE MEALS A DAY

Many persons are starving without any reason, with plenty of food to eat. They may have enough carbohydrates, fats, and proteins, but they may starve for lack of certain substances called *vitamins* (VY-tuh-minz). Without vitamins the body cannot work properly. Even though the vitamins are needed in very small amounts, they are so important that people can become ill and die for the lack of them. These people develop what doctors call a *deficiency* (deh-FISH-un-see) disease — a lack of something needed for good health.

Dr. Lind Cures Scurvy

In 1747 Dr. Lind, a sea surgeon in the British navy, did a remarkable experiment with twelve men who had scurvy. Scurvy was a disease that sailors developed on the long sea voyages of that time. Their gums bled

and started to decay; their knee joints swelled and grew weak. Because cuts and wounds would not heal, many were in danger of dying from loss of blood. Dr. Lind felt that there might be something missing from the diet of the sailors, so he planned his experiment to look for the cause of scurvy.

He gave three of the twelve men some vinegar, three some cider, three a mixture of mustard seed, garlic, and other herbs. These mixtures had been used for scurvy in the past but had never seemed to help. These were his controls. To the last three men he gave lemon juice. As Dr. Lind reported, the men who were given lemons (or limes, as the British called them) recovered so quickly that they were "appointed to nurse the rest of the sick." The British government soon ordered that all men at sea be given lemon juice regularly. Thus a trained scientist, a doctor, found both a cure and a way to prevent scurvy.

Now, as a result of a great deal more scientific work, we know that the juice of lemons, limes, oranges, grapefruit, tomatoes, and green vegetables has vitamin C, or ascorbic (as-KOR-bik) acid. Vitamin C prevents scurvy. Getting enough vitamin C keeps the skin and teeth healthy. It is also important for growth, and for keeping blood vessels and bones in good condition.

Mothers give orange and tomato juice to babies because milk does not give them enough ascorbic acid — vitamin C — for the health of the small blood vessels.

Dr. Eijkman and His Birds

Many scientists living in the late 1890's had begun to believe that wherever there was a disease, a germ could be found that had caused it. However, a disease called *beriberi* (BEHR-ee-BEHR-ee) for years had been causing death in China and the East Indies, but no one had found a germ that caused it. It was a disease of the nervous system which caused paralysis and death. Dr. Eijkman (EYK-man), who was working in a hospital in the East Indies, had been trying to find a germ that might be the cause of beriberi, but he had had no success. Then he began to study the diets of those who had the disease. He found that prisoners in the nearby jail, who were fed mainly brown rice (rice with the outer husks on the grains), never had beriberi.

Dr. Eijkman wondered if there were something in the husks of the rice that kept the prisoners from getting beriberi. So he decided to try an experiment using the chickens kept in the hospital yard. He fed white rice to some of the chickens and brown rice to others. Soon the chickens given the white rice began to get sick, while those given the brown rice stayed healthy. He was pretty sure, then, that he had found the cause of beriberi — a lack of something in the diet. That "something" was in the husks of the rice. He then began to feed brown rice to his patients, and those with beriberi began to get well. Did you notice that Dr. Eijkman used a control? What was it?

Today we know what it is in the brown rice husks that prevents beriberi. It is vitamin B_1, or *thiamine* (THY-uh-min). Other scientists building on Dr. Eijkman's work have found that not only brown rice but other whole-grain cereals, green vegetables, eggs, and yeast have thiamine.

In the last few years, scientists in the Philippines have wiped out beriberi. How have they done it? By adding vitamins to ordinary rice, so that even those who eat white rice will get the vitamins they would get in brown rice. Again, science is helping to save lives.

Vitamin B_1 not only prevents beriberi, but it also helps the nervous system and the intestines to work better. You need to eat foods with vitamin B_1 in them, so that you can keep healthy.

The nervous system and the digestive system also need vitamin B_2, or *riboflavin* (ry-boh-FLAY-vin). B_2 is found in meats, dairy products, and green vegetables.

Dr. Goldberger and Pellagra

In 1925, Dr. Joseph Goldberger of the United States Health Service was working in a certain southern town. Before him sat a tired-looking boy. The hands he held out for the doctor to see were covered with sores. The boy did not know why he was so tired, for he got enough sleep and plenty of food. He did not have enough energy to work or play. Dr. Goldberger did not have to ask the boy what was wrong. He knew. He was looking at a case of *pellagra* (peh-LAY-gruh), a disease caused by poor diet.

When the Health Service first sent Dr. Goldberger south to study pellagra, the doctor thought it might be a disease caused by a germ. One day he visited an orphanage. There he found that only the children between the ages of six and twelve had pellagra. He wondered why. He discovered that only children under six had milk to drink, and only those over twelve had meat. This made him suspect that pellagra was another disease caused by a lack of something in the diet. Given milk and meat, the children in the six-to-twelve age group got well.

Then Dr. Goldberger asked the governor of Mississippi if he could try an experiment on convicts in the state prison to find a sure proof that pellagra was caused by a poor diet. The convicts were to go free if they helped with the experiment. Twelve men volunteered. They were kept in clean rooms and were fed well except that they got no fresh vegetables, fresh meat, or milk. Within six months these men showed the red patches, the sores, and the lack of energy that go with pellagra. When fresh meat, vegetables, and milk were given to them again, they got well.

Dr. Goldberger knew, because of his earlier experiments, that the diet of the sick boy before him lacked fresh green vegetables, fruits, milk, or fresh meat. These foods have the vitamin called *niacin* (NY-uh-sin), another one of the B vitamins. Because of Dr. Goldberger's careful scientific work, we now know how to prevent pellagra.

Night Blindness, the Common Cold, and Vitamin A

In Labrador, during the winter, many natives suffer from a disease known as night blindness. They cannot see well in dim light. Night blindness is common there in the winter because the people do not get certain foods having vitamin A in them. The green plants which have the A vitamin materials cannot be had in Labrador during the winter season.

Even where you live, persons may

be suffering from night blindness. If so, they cannot see well enough to drive safely at night. Such night blindness is caused by a lack of vitamin A.

Vitamin A will help keep you from getting colds. When vitamin A is lacking in the diet, the linings of the throat and nose will get very dry. Doctors tell us that the common cold starts more easily when the linings of the nose and throat are dry.

If you get plenty of milk, butter, eggs, green vegetables, and especially yellow vegetables such as carrots and squash, you will get all the vitamin A you need. There is vitamin A also in cod liver, halibut liver, and shark liver. If you have many colds, the doctor may ask you to take some of these fish liver oils to add to your supply of vitamins A and D.

The "Sunshine" Vitamin

Vitamin D, found in cod and halibut liver oils, is often called "the sunshine vitamin." Without vitamin D your bones will not grow properly. This is so because the body cannot use calcium and phosphorus, two elements needed by the bones, without the help of vitamin D. If there is enough sunshine striking the skin, your body will make its own vitamin D. In winter or if you are indoors much of the time, you may need to take cod liver oil or one of the fish oils having vitamin D in it. Vitamin D also helps the body build up resistance to colds.

Searching for More Vitamins

Scientists are still looking for other vitamins. Vitamin K was discovered quite recently. This vitamin helps the blood to clot more easily. It is often given to a patient before an operation, to keep him from bleeding too much.

Vitamins are found in foods. If you eat a balanced diet of vegetables, fruit, meat, cereals, eggs, and dairy products, you should not have to take pills to get your vitamins. If you think you need vitamins, let your doctor prescribe them. Do not buy them, hit or miss, from a drugstore.

Before you leave the subject of vitamins, study Table 1, which shows the results of some experiments on animals. Do you see how there can be starvation on a full stomach? Perhaps you would like to try some of these experiments in your laboratory.

Minerals for Health and Growth

Have you ever heard someone say, "He is not worth his salt"? What did he mean? Where did this saying come from?

In some parts of the world salt used to be so scarce that it cost a great deal. This was true in Rome, 2,000 years ago. Roman soldiers were sometimes paid in salt, and they were glad to get it. It was a good man in those days who was worth his salt.

Salt was valuable because everybody needed it. To get it they were willing to pay a high price. Today, as in the days of Rome, common table salt is one of the minerals needed in the blood and other body cells for good health. Salt is a mineral made up in a combined form of the two elements, sodium and chlorine. Someone in your class may wish to prepare a special report on the subject of salt.

What other minerals do you need for growth and health? Why do you

TABLE 1 Vitamin Starvation — Its Cause and Cure

RAT
with adequate
diet except for
no vitamin A

+ vitamin A

Diet Wheat 120 grams
Dried beef 32 grams
Starch 150 grams
Salt 3 grams
Calcium carbonate 10 grams

Same diet—with vitamin A
Butter 30 grams

To get vitamin A in your diet
Eat butter, milk, eggs, carrots, green vegetables, cheese, fish oils.

RAT
with adequate
diet except for
no vitamin B

+ vitamin B

Diet White flour 150 grams
Butter 30 grams
Dried beef 15 grams
Starch 100 grams
Salt 3 grams
Calcium carbonate 30 grams

Same diet—with vitamin B
Yeast 5 grams

To get vitamin B in your diet
Eat whole grain and cereals, peas, green vegetables, lean meat, fruits.

GUINEA PIG
with adequate
diet except for
no vitamin C

+ vitamin C

Diet Oats 300 grams
Bran 270 grams
Dry beans (ground) 300 grams
Butter 30 grams
Salt 10 grams

Same diet—with vitamin C
Orange or tomato juice 100 cc.

To get vitamin C in your diet
Eat citrus fruits, tomatoes, green vegetables, drink fruit juices.

RAT
with adequate
diet except for
no vitamin D

+ vitamin D

Diet Yellow corn 150 grams
Gluten flour 40 grams
Salt 3 grams
Calcium carbonate 30 grams
No sunlight

Same diet—with vitamin D
Viosterol (containing vitamin D)
20 drops per 1,000 grams of diet

To get vitamin D in your diet
Eat milk products, eggs, fish oils.

U. S. DEPT. OF AGRICULTURE AND E. R. SQUIBB AND SONS

need them and where do they come from?

You need calcium and phosphorus for good growth of teeth and bones. One of the best sources of calcium and phosphorus is milk. Do you drink at least two or three glasses of milk daily? Young children should have a quart — four glasses. Other sources of calcium and phosphorus are dairy products, like cheese and eggs.

Some diseases can be traced to a lack of certain minerals. For instance, simple goiter, an enlargement of the thyroid gland in the neck, is due to lack of iodine. Iodine is found in the ocean and in some soils. Sea foods and seaweeds have iodine in them.

Certain kinds of *anemia* (uh-NEE-me-uh) are caused by lack of iron. In anemia there are not enough red blood cells in the blood, or not enough hemoglobin (HEE-moh-gloh-bin). Hemoglobin is the red compound that carries oxygen to all our cells. Iron is needed to form hemoglobin. Beef liver and heart, carrots, spinach, and other green vegetables are rich in iron.

Water Is Important

Do you know that about two-thirds of your body is water? Water in the bloodstream helps to dissolve and carry foods. Water helps us get rid of wastes through the kidneys and the sweat glands in the skin. To keep up the supply of water in your body, you should drink from six to eight glasses daily. How many have you had today?

Milk Makes Up for Mistakes

You must wonder just how it is possible for anyone to plan a balanced diet with so many things to take care of. But if you fill out your diet with milk, you will find that it will take care of some mistakes that may be made. Milk has proteins and fats in it, as well as carbohydrates. It has a good number of the vitamins you need except for vitamin C, which is present only in small amounts. It has many minerals in it, the most important of which is calcium. You ought to drink at least a pint of milk a day.

BALANCED DIET FOR BALANCED GROWTH

You are the person who has the care of your own growth. For best growth, you will need to eat the right amounts of carbohydrates, proteins, fats, vitamins, and minerals, and get enough water. No one can tell you just what you will need, but the United States government health services have a list of the food groups, which will help you make good plans for what to eat. These food groups are called "The Basic Seven." In your daily diet you should have:

1. Milk — one pint or more a day.
2. Eggs — one or more a day; at least four each week.
3. Meat, cheese, fish, or fowl — a serving a day.
4. Vegetables and fruits — green vegetables (lettuce, celery, cabbage, green peas, broccoli) and yellow vegetables (sweet potatoes, carrots, squash). A serving of one yellow and one green vegetable and a potato a day is desirable.
5. Citrus fruits — orange, grapefruit (whole or in juice).
6. Cereals and bread — especially bread made from whole grain (and

spread with butter or with margarine which has vitamins added).

7. Liquid — the equivalent of six to eight glasses of water.

If you have "The Basic Seven" you will be getting a balanced diet.

Preparing Food for the Good Diet

Would you throw good food away? Some people do. They pour the valuable vitamins down the sink. Nowadays, cooking food well means preparing it so that all the nutrients are saved. Cooking vegetables too long or in too much water destroys the vitamins. Do you cook vegetables in water and then throw the water away? If you do, you are wasting your money and taking chances with your health. Minerals, vitamin B_1, vitamin C, and vitamin K dissolve in water. Instead of pouring the cooking water down the drain, use it in soups, stews, and gravies.

Pressure cooking also saves many of the nutrients. The pressure cooker uses little water; instead, the food is cooked quickly under steam pressure. This quick cooking keeps the nutrients, including the precious minerals and vitamins, in the food itself.

It is good sense and good science to save nutrients. There is little point in buying food for its nutrients and then losing them down the drain.

25 Different kinds of food: *1*, foods high in protein; *3*, foods high in carbohydrates; *4*, foods high in fats. These are basic types of food. Vegetables (*2*) have in them all three types. How many of the foods pictured, or ones like them, have you eaten this week? *Project:* Make a study of the kinds of food eaten in different countries.

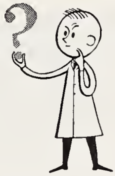
EZRA STOLLE

The Good Diet

Now it's up to you.

Starting today, keep a record of what you eat for three days. List the kinds of food and the amounts of each kind. Then figure the number of calories you get and the amounts of carbohydrates, fats, proteins, minerals, and vitamins (pp. 76 and 77). Remember that you should try to plan a well-balanced diet.

Are you really getting the diet that will keep you strong and healthy? Are you getting the diet which will keep your cells working properly? If not, start to do something about it today. It is important to you!



LOOKING BACK

Tool Words

Write out your own meaning of each word and then check it with the glossary. Do you have to change your meaning to make it right?

- calorie (large)
- deficiency disease
- nutrients (carbohydrates, proteins, fats, minerals, vitamins, water)
- oxidation
- vitamins (thiamine, niacin, riboflavin)
- cell
- nucleus
- cell membrane
- cytoplasm
- protoplasm
- organ
- tissue
- organism

Test Yourself

Copy the sentences in your notebook and fill the blanks. DO NOT MARK THIS BOOK.

1. A calorie is the amount of heat needed to raise 1,000 cubic centimeters of water . . . degree centigrade.
2. The six nutrients found in foods are . . . , . . . , . . . , . . . , . . . , ...
3. Energy for bodily heat and activity is supplied by . . . .
4. . . . foods are needed for building new cells.
5. Two foods containing

   Vitamin A are . . . , ...
   Vitamin B_1 (thiamine) are . . . , ...
   Vitamin C are . . . , ...
   Vitamin D are . . . , ...

6. A cell is made up of . . . . Near the center of the cell is its . . . , surrounded by . . . . The outer covering of the cell is called the . . . .
7. The smallest unit of living matter in the body is . . . . When they work together in groups to do a specialized work, they form . . . .
8. When oxygen combines with food nutrients in the cells, . . . takes place.

GOING FURTHER

In the Laboratory

1. *Testing foods for nutrients*

a. For starch. Iodine turns starch a blue-black color. Mix a teaspoonful of cornstarch with water. Add a few drops of 1% iodine solution and you will see this blue-black color. Then test other foods. If you boil a little of the food in a test tube before you add the iodine, the reaction will show up more quickly.

b. For fat. Rub the piece of food to be tested on a piece of brown paper. If it contains fat, it will leave a greasy spot on the paper. Hold it up to the light and the spot will be bright.

c. For sugar. Mix a teaspoonful of sugar with water in a test tube. Add a little Benedict's solution to the mixture and boil it. Foods with glucose or other simple sugars will turn brick-red.

d. For protein. This test is done with nitric acid, which must be handled carefully. *Acid burns the skin!* Put some egg white into a test tube with enough nitric acid to cover it. Heat it over a Bunsen burner until it boils. Carefully pour off the acid, rinse the egg white, and then add some ammonia water. If there is protein, the egg white will turn an orange-red.

2. *Finding how diet affects the growth of rats.* Take two pairs of young rats just weaned. They should be of the same strain or, better yet, from the same litter. Feed them both the same diet of white bread, water, and green vegetables. To the diet of one pair add half a cupful of milk a day. Weigh them regularly every two days. What are your results? Be sure to keep careful records, and have somebody check your work.

3. *Experimenting with vitamin B_1.* Take four young pigeons. Feed two of the pigeons brown rice, and the other two white rice. Be sure to give them enough water. Watch them carefully. In about three to four weeks, you will begin to see results. Look for signs of staggering, weakness, and inability to stand.

After you have seen the effect of the lack of vitamin B_1, feed one of the affected pigeons some green peas. Give the other some vitamin B_1 by means of a medicine dropper. Which one recovers faster? Where was the vitamin B_1 in the food of the pigeons which stayed healthy?

Put on Your Thinking Cap

1. Bill thought he was overweight. After all, he weighed 10 pounds more than his brother who was a year older. Yet he ate about the same food as his brother. What should Bill do?

2. In certain parts of the country, corn bread, molasses, and salt pork furnish the major part of the diet. What is lacking in this diet? What disease may result if this diet continues?

3. Green vegetables contain a vitamin that helps growth. How would you plan an experiment to prove this? (Suppose you had 200 white rats on which you could experiment.)

Adding to Your Library

BOOKS

The books in the following list will give you material for class reports. Each book is an adventure in reading.

1. *The Wonderful World of Medicine* by Ritchie Calder, Garden City (Doubleday), 1958. Many colored pictures describe the story of medicine from the magic of the witch doctor to medicines of the space age.
2. *Your Allergy and You* by Kay Kempton Haydock, Holt, 1958.
3. *Polio and the Salk Vaccine* by Alton L. Blakeslee, Grosset, 1956.
4. *Health in Your Daily Living* by Josephine L. Rathbone, Francis L. Bacon, and Charles H. Keene, Houghton, 1958.
5. *The Wonderful World of Food* by John Boyd Orr, Garden City (Doubleday), 1958. This is a big picture book in color, all about getting food for a hungry world.
6. *Your Food and You* by Herbert S. Zim, Morrow, 1957.
7. *Your Health and Safety*, 4th edition, by Jessie W. Clemensen and others, Harcourt, Brace, 1957.
8. *Chemistry Creates a New World* by Bernard Jaffee, Crowell, 1957. How did the chemist make wonder drugs, nylon, and synthetic rubber? What are titanium and zirconium? Read in this book about many things the chemist makes for us.

PAMPHLETS

1. *Overweight and Underweight.*
2. *Hidden Calories That Tip the Scales*, both published by Metropolitan Life Insurance Co., Health and Welfare Division, New York.
3. *National Food Guide*, U.S. Department of Agriculture, Bureau of Human Nutrition and Home Economics, Washington, D.C.
4. *How to Live Longer* by R. Will Burnett, Science Research Associates, Chicago, 1954.

A Bit of Research

Analyzing vitamin content. How much vitamin C is there in different juices? A substance which we will call *indophenol*[1] (in-doh-FEE-nohl) is colored blue. Vitamin C turns it colorless. (Before the indophenol turns colorless, it may turn pink. Several more drops of juices containing vitamin C will make the pink disappear.) A test performed by one student showed that 27 drops of frozen orange juice turned 5 cubic centimeters of indophenol (about an inch of fluid in a test tube) to white. Your teacher will give you a solution of the indophenol when you are ready for your experiment. You might compare orange juice, grapefruit juice, milk, and other liquids or juices for vitamin C content.

Plan your experiment carefully.

What apparatus will you need?

How will you measure the amount of juice you will add?

How will you be sure that you have the same amount of indophenol in each tube?

How will you record your results?

How will you report your results?

Plan a project which will permit you to analyze the vitamin content of different varieties of orange.

Careers for You

Of course, we always need *doctors* and *trained nurses*, but do you know that hundreds of *chemists* and *biologists* are needed to help as *research workers* in public health departments and in large commercial laboratories? Here may be the place for you.

Men and women trained in the science of foods are always in demand. They are called *dietitians.* Hospitals, schools, factories, and restaurants need dietitians. Would you like to be a dietitian?

[1] This may be obtained under the name dichlorobenzenoneindophenol from a chemical supply house.

HAROLD M. LAMBERT
FROM FREDERICK LEWIS

Daily Vitamin Needs

	Vitamin A, International Units	Thiamine, Milligrams*	Riboflavin, Milligrams	Niacin, Milligrams	Ascorbic Acid, Milligrams	Vitamin D, International Units
GIRLS						
13 to 15 years	5,000	1.4	2.0	14	80	?
16 to 20 years	5,000	1.2	1.8	12	80	?
BOYS						
13 to 15 years	5,000	1.6	2.4	16	90	?
16 to 20 years	6,000	2.0	3.0	20	100	?

* 1,000 milligrams = 1 gram; 28.5 grams = 1 ounce.

FOOD AND YOU

Daily Diet for a Moderately Active Man

Kind of Nutrient	*In Units*
Energy (carbohydrates and fats)	3,000 calories
Protein (varied)	70 grams
Calcium	1 gram
Iron	12 milligrams
Vitamin A	5,000 International Units
Thiamine (Vitamin B)	1.5 milligrams
Riboflavin (Vitamin G)	1.8 milligrams
Niacin	15 milligrams
Ascorbic acid (Vitamin C)	75 milligrams

Calorie Needs for Different Activities *

Activity	*Calories per Pound of Your Weight, per Hour*
Bicycling (moderate speed)	1.1
Bicycling (racing)	3.4
Carpentering, heavy	1.0
Dancing	1.7
Dishwashing	0.5
Dressing and undressing	0.3
Eating	0.2
Playing Ping-pong	2.0
Running	3.3
Sawing wood	2.6
Sitting quietly	0.2
Standing relaxed	0.2
Swimming	3.6
Typewriting rapidly	0.5
Violin playing	0.3
Walking (3 miles per hour)	0.9
Writing	0.2

Using this table: Suppose you weigh 120 pounds. For a good walk you will need 120 × 0.9 (see above) = 108 calories per hour. Add to this 65 calories per hour so on. Total = 173 calories. This is very approximate and may not work for all people, especially for very heavy and very thin individuals.

* Adapted from *Foundations of Nutrition* by Mary Swartz Rose, The Macmillan Company, 1938, pp. 606–607. Reprinted by permission.

Sources of Your Calories, Carbohydrates, Fats, and Proteins *

Food	*Calories*	*Carbohydrates, Percentage*	*Fat, Percentage*	*Proteins, Percentage*
APPLE, *raw, 1 large 3 in. diameter*	97	15	0.4	0.3
BACON, *5 in. strip, crisp*	31	2	27	14
BANANA, *1 medium*	99	23	0.2	1.0
BEANS, *navy, pea, kidney, ½ cup*	105	62	2	22
BEANS, *snap, ½ cup*	42	8	0.2	2
BEEF, *1 slice 3 × 2 × ½ in.*	233		16	23
BREAD, *enriched white, 1 slice*	65	52	2	8
BREAD, *whole wheat 60%, 1 slice*	72	46	3	9
BUTTER, *1 pat*	73	0.4	81	0.6
CABBAGE, *fresh, ½–¾ cup, shredded*	15	5	0.2	1
CARROTS, *raw, 1 large, ¾ cup (cubes)*	45	9	0.3	1
CHEESE, *American Cheddar, 1 oz.*	112	2	32	24
CHICKEN, *roasted, 3 slices, 3½ × 2½ × ¼ in.*	193		9	28
CODFISH, *1 cake, 2½ in. diameter*	122	16	11	11
EGG, *whole, 1 medium*	79	0.8	12	13
FRANKFURTER, *boiled, 1 average*	121	3	14	15
GRAPEFRUIT, *½ small*	44	10	0.2	0.5
ICE CREAM, *plain, ⅙ quart*	210	21	12	4
LAMB CHOP, *shoulder, 1 average chop*	245		22	17
LIVER, *beef, fried, 1 average slice*	82	8	8	25
MILK, *whole, 6 oz.*	123	4	3	3
ORANGE, *whole, 1 medium*	76	11	0.2	0.9
POTATO, *white, cooked, 1 medium, in skin*	129	19	0.1	2
SPINACH, *fresh, ⅔ cup*	25	3	0.3	2
TOMATOES, *canned, ½ cup*	21	4	0.2	1

* Adapted from *Food Values of Portions Commonly Used*, by A. de P. Bowes and C. F. Church.

Sources of Your Vitamins and Minerals

Food	Calcium, Milligrams*	Iron, Milligrams	Phosphorus, Milligrams	Vitamin A, International Units*	B_1, Thiamine, Micrograms	B_2, Riboflavin, Micrograms	B_6, Niacin, Milligrams	C, Ascorbic Acid, Milligrams	Vitamin D, International Units
APPLE, *raw, 1 large, 3 in. diameter*	9	0.5	15	135	60	30	0.3	8	
BACON, *5 in. strip, crisp*	2	0.1	16		60	10	0.3		
BANANA, *1 medium*	8	0.6	28	430	90	60	0.6	10	
BEANS, *navy, pea, kidney, ½ cup*	44	3.1	139		180	72	0.6		
BEANS, *snap, ½ cup*	65	1.1	44	630	80	100	0.6	19	
BEEF, *1 slice 3 × 2 × ½ in.*	13	3.5	250		122	153	5.3		
BREAD, *enriched white, 1 slice*	14	0.5	25		60	37	0.6		
BREAD, *whole wheat 60%, 1 slice*	14	0.6	42		84	49	0.9		
BUTTER, *1 pat*	2		2	330		1			4
CABBAGE, *fresh, ½–¾ cup, shredded*	23	0.3	16	40	35	30	0.1	26	
CARROTS, *raw, 1 large, ¾ cup (cubes)*	39	0.8	37	12,000	70	60	0.5	6	
CHEESE, *American Cheddar, 1 oz.*	247	0.2	173	493	11	142			
CHICKEN, *roasted, 3 slices, 3½ × 2½ × ¼ in.*	22	2.7	305		92	214	10.2		
CODFISH, *1 cake, 2½ in. diameter*	11	0.8	71	130	44	49	0.7	?	5
EGG, *whole, 1 medium*	27	1.4	105	570	60	170			45
FRANKFURTER, *boiled, 1 average*	5	1.4	98		111	135	1.2		
GRAPEFRUIT, *½ small*	17	0.3	18		40	20	0.2	40	
ICE CREAM, *plain, ⅙ quart*	132	0.1	104	540	40	190	0.1		
LAMB CHOP, *shoulder, 1 average chop*	9	2.3	168		153	196	4.4		
LIVER, *beef, fried, 1 average slice*	6	6.1	187	9,600	115	1,190	6.8	?	23
MILK, *whole, 6 oz.*	212	0.1	167	288	72	306	0.2	2	4
ORANGE, *whole, 1 medium*	50	0.6	35	285	120	45	0.3	74	
POTATO, *white, cooked, 1 medium, in skin*	17	1.1	84	30	168	55	1.6	17	
SPINACH, *fresh, ⅔ cup*		3.0	55	9,420	120	240	0.7	59	
TOMATOES, *canned, ½ cup*	11	0.6	27	1,050	50	30	0.7	16	

* The International Unit is the standard measurement used for vitamins. A milligram equals 1/1,000th of a gram; a microgram equals 1/10,000th of a gram. On the basis of these units boys and girls need: Vitamin A, 5,000; thiamine (B_1), 1,500; riboflavin (B_2), 2,000; niacin (B_6), 15; ascorbic acid (C), 85. Of the minerals, you will need: calcium, 1,350 milligrams, and iron, 15 milligrams; the exact quantity of phosphorus needed is unknown.

PHILIP GENDREAU

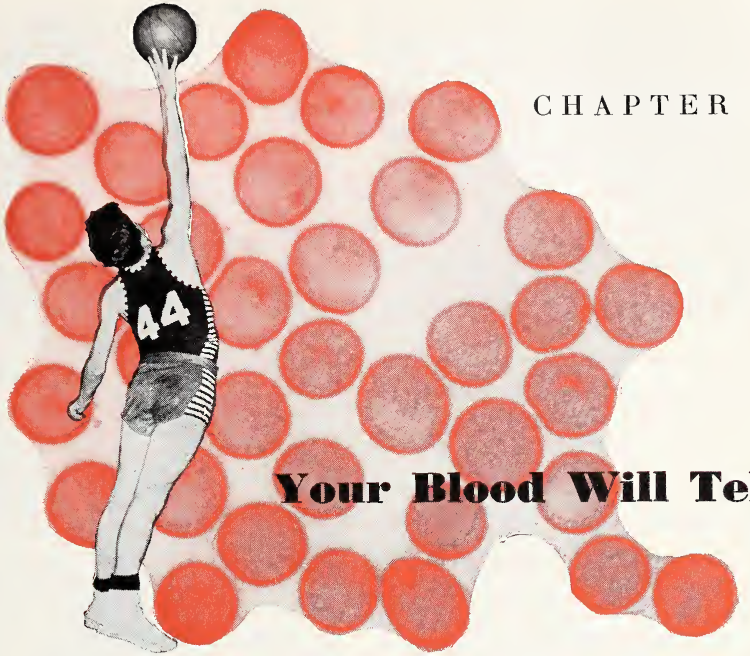
Daily Calorie Needs for Different Kinds of Work

Kind of Work	*For Men of Average Weight (154 pounds) Ages 20–60*	*For Women of Average Weight (130 pounds) Ages 20–60*
VERY ACTIVE WORK Truck loading, combat duty or soldiers, any work that needs heavy lifting or pulling	4,500	3,000
FAIRLY ACTIVE WORK Hiking (with full knapsack), marching, selling (door to door), any walking with moderate loads	3,000	2,500
LIGHT WORK Selling behind counter, typing, active office work, any work in which the person is seated but moves arms and legs or walks about freely; no heavy lifting	2,700	2,300
INACTIVE WORK Office work, information booth, any work in which the person is seated but needs to move arms and legs very little	2,400	2,100

FREDERICK LEWIS

HOBART FROM MONKMEYER

CHAPTER 4



Your Blood Will Tell

As the boy hits the floor he will be breathing harder. His lungs will be taking in more air. Useless, unless the red blood cells pictured carry the oxygen in the air to his cells. You are as healthy as your blood.

HAVE YOU HAD your health checked this year? When was the last time you had a physical examination?

One of the best ways to know the condition of your health is to have a check-up every six months or at least once a year. The doctor will examine your body carefully. He may find something that needs watching, or he may catch a disease in time to prevent a long illness. Most times, however, he will probably find that you are in good health.

The doctor gets his clues to your health by noting how you look and by using some of his instruments. One of these instruments is the *stethoscope* (STETH-uh-skohp) (Fig. 26). With it he listens carefully to your heartbeat. What the doctor hears may tell him whether your heart is keeping your blood circulating properly. When your blood reaches every part of your body, your cells are getting food and oxygen. It is only through your blood that food can get to the different parts of your body.

The doctor may also examine a sample of your blood under his microscope. In this way he can see the

blood cells, which are too small to be seen by the naked eye. Your blood gives the doctor a pretty good idea of your general health. If you have not had a check-up lately, why not discuss it with your parents?

THE MAKE-UP OF THE BLOOD

If you could see your blood under the microscope, what would it look like? Look at a part of a drop in Fig. 27 and find out.

Blood Cells

Notice the great number of round, disk-shaped cells. These are the red blood cells. There are about 5 million of them in a very tiny drop of blood (1 cubic millimeter). Red cells have in them a substance called hemoglobin. This hemoglobin gets bright red when it combines with oxygen. Your red blood cells, sometimes called red *corpuscles* (KOR-pus-'lz), have no nucleus. They are made in the marrow of the bones. Some of the cells are stored in the spleen, a small organ near the stomach. Red blood cells are carried in the blood and do not move around by themselves.

The other cells in the blood (Fig. 27) are the white blood cells. They have a nucleus but no hemoglobin. In a normal drop of blood there are 5,000 to 7,000 of these white blood cells. Like the red blood cells, white cells are carried in the blood. Unlike the red cells, white blood cells can move about by themselves. If you were watching such a cell move, you would see it push out a short bulge,

PINNEY FROM MONKEYER

26 The doctor uses his stethoscope to find out how well the newborn baby's heart is pumping to all parts of its body.

then another, and another. These bulges serve two purposes: to enable the cell to move about and to pick up particles, like bacteria, that may get into the blood.

Both red and white cells are carried about in a straw-colored fluid. This fluid is called the *plasma* (PLAZ-muh). Plasma is mainly water and makes up the liquid part of the blood.

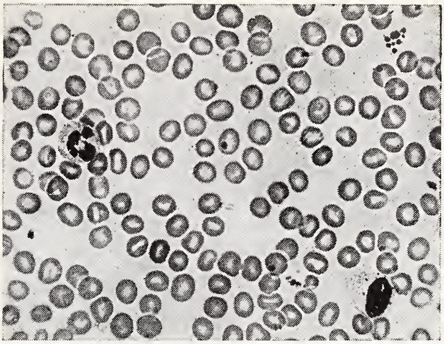
Your Blood Cells in Action

Have you the right number of blood cells? If you have ever had your blood cells counted, you know that the doctor takes a drop of blood from your finger or the tip of your ear. Then he puts the blood on a glass slide in a special way and makes a count under the microscope.

Healthy blood should have about 5 million red cells in each drop. Why is this number important? As you have learned, they have the red substance, hemoglobin, which carries oxygen to every other body cell. In the cells of the body the oxygen unites with the food. As you may remember, the food burns (without a flame, of course) and in this way supplies energy for your daily work and play. Therefore, when the number of red blood cells is low, the body cannot get the oxygen it needs for good health.

Have you ever had a white blister — white because of the pus in it? Did you know that this showed that the white blood cells were in action? It happens this way: white blood cells attack any bacteria that enter the body. The number of white cells in your blood gets larger as the cells swarm to the attack. Thus, the normal number of 5,000 to 7,000 white cells in each drop of blood goes up when your body is invaded by bacteria. Suppose your blood count shows 12,000 white cells in each drop of blood. This high count will probably mean that bacteria have entered the body and that the white cells are fighting them. It may mean that you have an infected appendix. At any rate, the doctor will begin to look for the source of infection when he finds a high white-cell count.

When you cut your finger, bacteria can enter the wound. The white cells may be able to heal the wound quickly, especially if you help them by washing the wound and applying an antiseptic. If, however, the finger swells, turns red, and throbs, you will know that the white cells may need help from the doctor. The pus that forms around an infected wound contains thousands of white cells that have died in the battle against the bacteria.



GENERAL BIOLOGICAL SUPPLY HOUSE

27 Imagine the face of a clock. At 5:00 and 9:00 are two large white blood cells; the dark spots are their nuclei. The other cells are red blood cells.

The Plasma

Your blood plasma plays just as big a part in keeping you healthy as do the red and white blood cells which are to be found in it. Dissolved in the plasma are all the food nutrients your body uses for energy and growth. Carbohydrates, proteins, minerals, and vitamins are dissolved and carried in the plasma to all the body cells.

The plasma also has substances which destroy different kinds of disease germs. Such substances are called *antibodies*. One kind kills typhoid germs. Another kind, about which

you will read later, makes harmless the poisons made by diphtheria germs. Antibodies are put into your blood plasma when you are vaccinated or given diphtheria shots.

In a small laboratory at Harvard Medical School in the 1920's, Dr. Edwin J. Cohn began a study of human blood.

World War I had shown the need of blood for wounded soldiers. In World War II, the need for blood and blood plasma for transfusions became greater. Did you ever have a blood transfusion? When you have lost blood in an injury or an operation, doctors usually have one or more pints of blood of the same type as yours put into your veins.

At the beginning of World War II, the Red Cross had a supply of blood on hand, but it was being used up rapidly. They feared their supply would run out. So Dr. Cohn was asked to search for a blood substitute that might be used in transfusions.

Dr. Cohn could find no good substitute for human blood, but he did make an important discovery. He found that he could separate human blood into different parts. He found five different parts or fractions of blood plasma (the liquid part of the blood). Some of them were already known.

Doctors thought that one of these materials in plasma, *gamma globulin*, might prevent infantile paralysis (polio). But they found that the prevention did not last long. Later, scientists learned to grow the polio virus outside the body and a successful vaccine was prepared by Dr. Jonas E. Salk of the University of Pittsburgh.

In a report to the American Chemical Society in 1949, Dr. Cohn told of several more fractions of blood plasma that he had recently found. Work is going on to discover a use for them, especially in getting blood to clot faster. But Dr. Cohn, who died in 1953, was fond of saying, "It is my work to find these fractions in plasma. It is the work of physicians to put them to use in curing the sick."

So the work with blood plasma goes on. *Serum albumin* (SEER-'m al-BYOO-min), which makes up the largest part of the plasma, is used to treat shock and severe burns. Gamma globulin, as you have already read, has been used in the fight against polio. It is also used to prevent measles and jaundice, a disease of the liver.

Fibrinogen (fy-BRIN-oh-jen), another part of the plasma, helps to clot your blood. When you have a cut, the fibrinogen is turned into a substance called *fibrin*. Fibrin is made up of small fibers which weave together to form a covering or clot over the wound. It stops the flow of blood and keeps out bacteria. Without fibrinogen in the blood, you could bleed to death.

There is another group of special substances carried by your blood. They are called *hormones* (HOR-mohnz). Hormones have a great deal to do with your height, the growth of your bones, your weight, and even your behavior. These hormones are made in glands in different parts of your body and sent into the blood stream. For example, a growth hormone is partly responsible for the growth of your body. This hormone is made in a gland found on the lower surface of your brain, just above the center of the roof of your mouth. Too much growth hormone may produce a giant. Too little may produce a midget.

You can see that the red and white blood cells and the blood plasma are all very important to good health. But a healthy blood stream depends upon what you eat, drink, and breathe. How do food substances get into the blood plasma? Let us go into the laboratory and find out.

TRANSFORMING THE FOOD YOU EAT

The food which you chewed and swallowed at your last meal is now finding its way through a long food tube about 25 feet in length. Somehow the food must get out of this tube into your blood plasma. How is it done? What happens to your food after you swallow it?

Food in the Mouth

Let us begin with the first part of the food tube, the mouth. Take a plain soda cracker. Divide it into four parts. First test one part for starch with iodine. The cracker turns blue, showing that the cracker contains starch. Test a second part for simple sugars by boiling it in a test tube with Benedict's solution. Since it does not turn green or red, you know that there are no simple sugars in the piece of cracker.

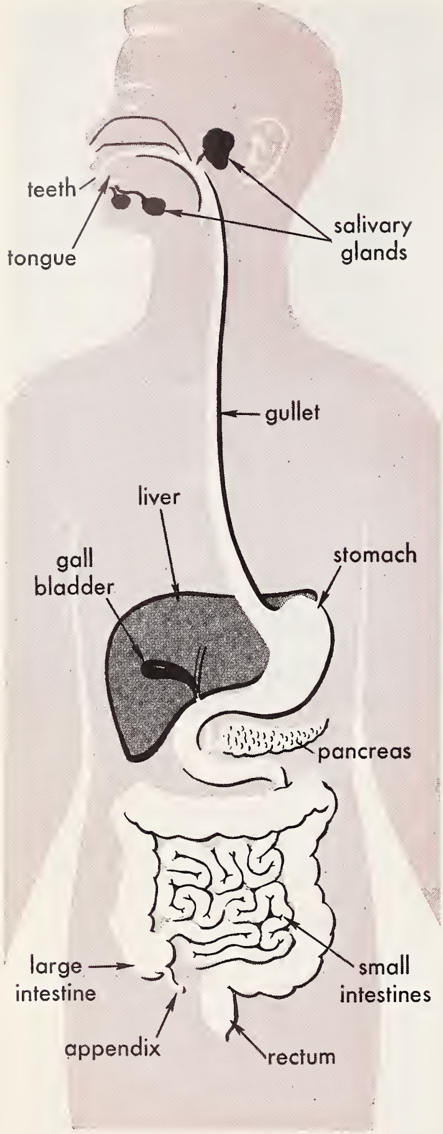
Now take one-quarter of the cracker and chew it slowly. Don't swallow it. Do you sense any change in the taste of the cracker? Is it sweeter, perhaps? After a few seconds, put this chewed mixture into a test tube. Now test this chewed cracker, which has been mixed with the saliva in your mouth, by boiling it with Benedict's solution. It turns a brick red, showing that simple sugars are now present.

AMERICAN RED CROSS

28 The wife of a Marine helps her fighting husband by giving blood at her Red Cross center. If blood is lost, it must be replaced. Blood carries oxygen and digested food to all the cells of the body. It removes wastes and carbon dioxide from the cells.

To check on this experiment, you would have had to test your saliva alone with Benedict's solution — before you chewed the cracker, of course. The saliva solution does not turn red. So there is no sugar in the saliva. Where, then, did the sugar come from in the chewed cracker? One more experiment may help to answer the question.

Crumble the last quarter of the cracker into a test tube and add to it an inch of saliva (collected earlier



29 In this diagram, trace what happens to a sandwich as it is digested in the food tube. What happens in the mouth? the stomach? the intestines? What does the pancreas do? Which of these structures have glands in them? Why not draw a larger chart for your classroom wall?

in a test tube). Shake up the mixture and keep the tube warm in the palm of your hand. After five minutes, test for sugar. The brick-red color shows up. Sugar is now present. What happens when you chew foods that contain starch?

Biologists have discovered that saliva has in it a substance called an *enzyme* (EN-zyme). The enzyme in saliva breaks down nutrients into simpler chemicals. The enzyme itself is not changed, even though it changes the food it is mixed with.

Enzymes in the Food Tube

That is not the whole story. Enzymes are produced not only in the mouth but also in the stomach and small intestine. The parts of the body which make enzymes are called glands (Fig. 29). Scientists have been able to get these enzymes from the glands of cattle. Now many enzymes can be bought at the drugstore on a doctor's prescription.

All of these enzymes break down the complex foods that we eat into simpler substances. The powerful enzymes made by the glands of the stomach and intestines change proteins, fats, and starches into simpler substances. *Digestion* is the process of breaking down complex food nutrients into simple substances. The job of your food tube is to digest your food.

Enzymes in the Stomach

In the lining of the stomach are thousands of tiny glands that pour *gastric* (GASS-trik) *juice* into the stomach. In this digestive juice is the enzyme *pepsin* and also some hydrochloric acid. Pepsin, with the help of

hydrochloric acid, breaks down proteins into simpler proteins. The pepsin cannot do its work properly without the aid of the hydrochloric acid.

Fats are not very much changed in the stomach.

Enzymes in the Small Intestine

After the enzymes in the stomach have had enough time to digest the food proteins, the valve at the lower end of the stomach opens and allows the now liquid food to pass on. The muscles in the lining of the stomach and intestines keep pushing the food along.

The enzymes found in the small intestine are made by a digestive gland called the *pancreas* (PAN-kree-us). The pancreas is found near the beginning of the small intestine and is joined to it by a small tube.

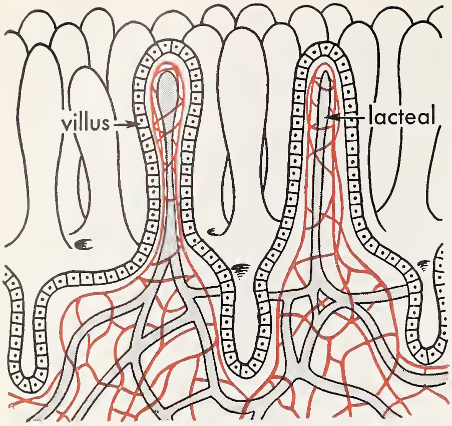
The pancreas makes *pancreatic* (pan-kree-AT-ik) *juice*, a powerful mixture of enzymes. Pancreatic juice can break down all the food nutrients — carbohydrates, fats, and proteins. And so the greatest part of digestion takes place here in the small intestine, where pancreatic juice does its work. The liquid food which came from the stomach is also mixed with other juices in the small intestine.

Bile made by the liver also flows into the small intestine to help break down the fats. It is the pancreatic juice, however, that digests the fats. The bile helps only by making it easier for the pancreatic juice to do its work.

During digestion, carbohydrates, proteins, and fats are broken down

TABLE 2 The Enzymes Which Digest Your Food

Enzyme	*Place Produced*	*What It Does*
Ptyalin (TY-ah-lin)	Mouth	Breaks down starch to sugar in the mouth
Pepsin (PEP-sin)	Stomach	Breaks down proteins to simpler substances
Trypsin (TRIP-sin)	Pancreas (a gland near the small intestine). The pancreatic juice is sent into the small intestine	Breaks down protein to soluble amino acids
Steapsin (stee-AP-sin)	Pancreas	Breaks down fats into fatty acids and glycerin
Amylopsin (am-uh-LOP-sin)	Pancreas	Breaks down any undigested starches into glucose
Enzymes in intestinal juice	Intestine	Breaks down any undigested food
	RESULTS OF DIGESTION	
All enzymes	In the alimentary canal	Produce soluble materials: Glucose from carbohydrates Amino acids from proteins Fatty acids, Glycerol (GLISS-er-ol) } from fats



30 Villi in the intestine. The colored lines show microscopic capillaries. Can you see why digested food goes easily into each villus through the membrane made up of a single layer of cells? Fats go into the lacteals.

into simple substances. In other words, the food is digested. These simple substances are now ready to be taken into the blood.

How does the digested food get out of the food tube into the blood?

INTO THE BLOOD

Right now, inside you, food substances are being carried by the blood stream to every part of your body. Food is being carried to your eyes and eye muscles, to the muscles that are helping you hold this book, to your brain, to your lungs, even to your heart, which is pumping your blood. How did the digested food get into your blood?

Passing Through Membranes

If you could examine the membrane that forms the wall of the small intestine, you would find that it is not smooth. It is covered on the inside with tiny tubelike structures called *villi* (VIL-eye) (Fig. 30). In each villus there is a network of the tiniest blood vessels in the body, called *capillaries* (KAP-'l-air-eez). These tiny tubes are filled with blood. They have thin walls through which digested food passes easily. Shortly after the digested food passes through the walls of the villi, it reaches the capillaries.

Simple proteins and sugar pass into the capillaries and thus into the blood. Digested fats, however, go into special structures in the villi, called *lacteals* (LAK-tee-ulz) (Fig. 30). Finally, the fats, too, reach the blood stream.

This passing through of digested food into the villi is called *absorption.*

Examine the diagram of the villus in Fig. 30. Notice the space inside each villus between the wall of the villus and its capillaries. In your body, this space is not empty; it is filled with a colorless fluid like blood plasma, called *lymph* (LIMF). The lacteal is also filled with lymph. Absorption of digested food, therefore, takes place first through the wall of the villus into the lymph. Then the digested food goes into the capillaries inside the villus.

From the Blood to Every Cell

Food would be of little use to you if it were to stay in the capillaries of the villi. Of course, it doesn't stay there. It is carried to every cell in your body. How is this done?

Feel your pulse by placing the tips of your two middle fingers on the inner side of your wrist. Count the beats per minute. You will find that your pulse beats from 65 to

85 times per minute. The average is about 72. This pulse beat felt at the wrist starts at your heart, almost three feet away.

Your heart is made of thick muscle. As this muscle works, it pumps blood to every part of your body, in round numbers, about 70 times a minute! Seventy times a minute is 4,200 times an hour — over 100,000 times a day! This steady pumping never stops as long as you live. It takes the blood from the capillaries of the villi and sends it to larger blood vessels. Just as small side roads or streets run into main streets and finally to the town, so capillaries from the villi lead to larger vessels which lead finally to the heart.

Where does the heart send the blood that pours into it? To every cell in the body. If you examine the circulation of blood in your arm, you can get an idea how blood reaches the cells of any part of the body.

Circulation in the Arm

Examine the circulation of blood in one of your arms. Hold your arm down for a minute. The bluish blood vessels you see are *veins*, which carry blood to the heart. Your other set of blood vessels, the *arteries*, are buried deeper in your tissues. It is the arteries that carry blood away from the heart to all parts of your body (Fig. 32).

Your heart pumps the blood into the largest artery in your body, the *aorta* (ay-OR-tuh). The blood then goes into the main artery of the arm. Like all the arteries, this artery carries blood away from the heart. From this main artery of the arm, smaller arteries branch out. These branch again and again into smaller and smaller arteries. The smaller arteries finally become tiny capillaries. These tiny, thin-walled capillaries form a network reaching all the cells in your arm. You cannot prick your finger without piercing a capillary.

The artery capillaries join with the vein capillaries, and the blood starts its journey back to your heart (Fig. 32). The vein capillaries become small veins; these become larger veins; these then join the large vein which enters the heart.

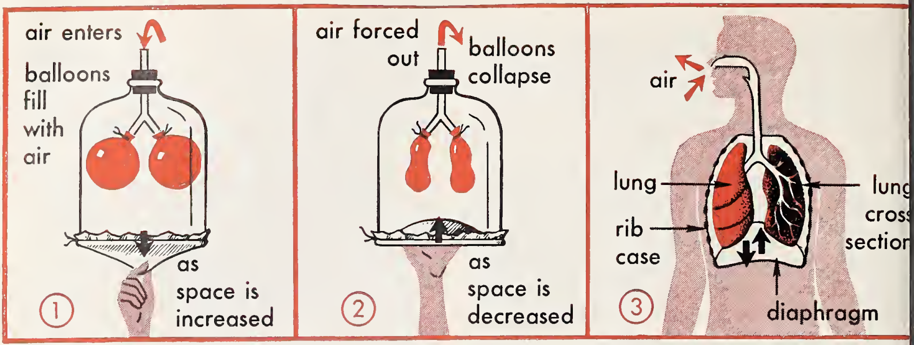
Look at Fig. 32 again. Do you see that the blood flows in a closed circuit? It flows from the heart to the arteries, to the veins, then back to the heart.

BRIGHT RED BLOOD TO EVERY CELL

Even if dissolved food did reach every cell in your body it could not be used unless there were another important substance there. From your earlier reading you probably have guessed what this substance is. Yes, it is oxygen. It is oxygen which makes your blood bright red. And bright red blood is absolutely necessary for good health and good growth. Without bright red blood, your cells could not burn, or oxidize, your food.

How does oxygen get into your blood? You perhaps can answer this question yourself by this time. Try it now. Then read on in this section to check yourself.

First, air enters through your nose and is warmed and moistened as it goes through the nose passages. At the back of the mouth it enters the



31 *Project:* Make this model and demonstrate it in class. Why does air enter in *1*? Why does air leave in *2*? Notice that the balloons represent the lungs; the rubber sheet, the diaphragm; and the glass jar, the rib case and body wall.

windpipe. The windpipe divides into two branches, the *bronchial* (BRONK-ee-ul) *tubes*. These tubes divide again and again, each tube ending in a group of thin-walled air sacs (Fig. 33).

How Air Gets into the Lungs

About a pint of air enters your lungs at one breath. Most people think that air is pulled into the body by the lungs. Not at all. Pull in your diaphragm as far as you can. Your diaphragm is a flat sheet of muscle just below the chest cavity (Fig. 31). Now try to breathe. It is almost impossible because you are not letting your diaphragm relax and expand.

Take a bell jar and tie a sheet of rubber over the wide opening at its base. The sheet of rubber is like your diaphragm. The bell jar would be your chest cavity. Complete your model of the chest cavity by attaching two balloons to a Y tube, as shown in Fig. 31.

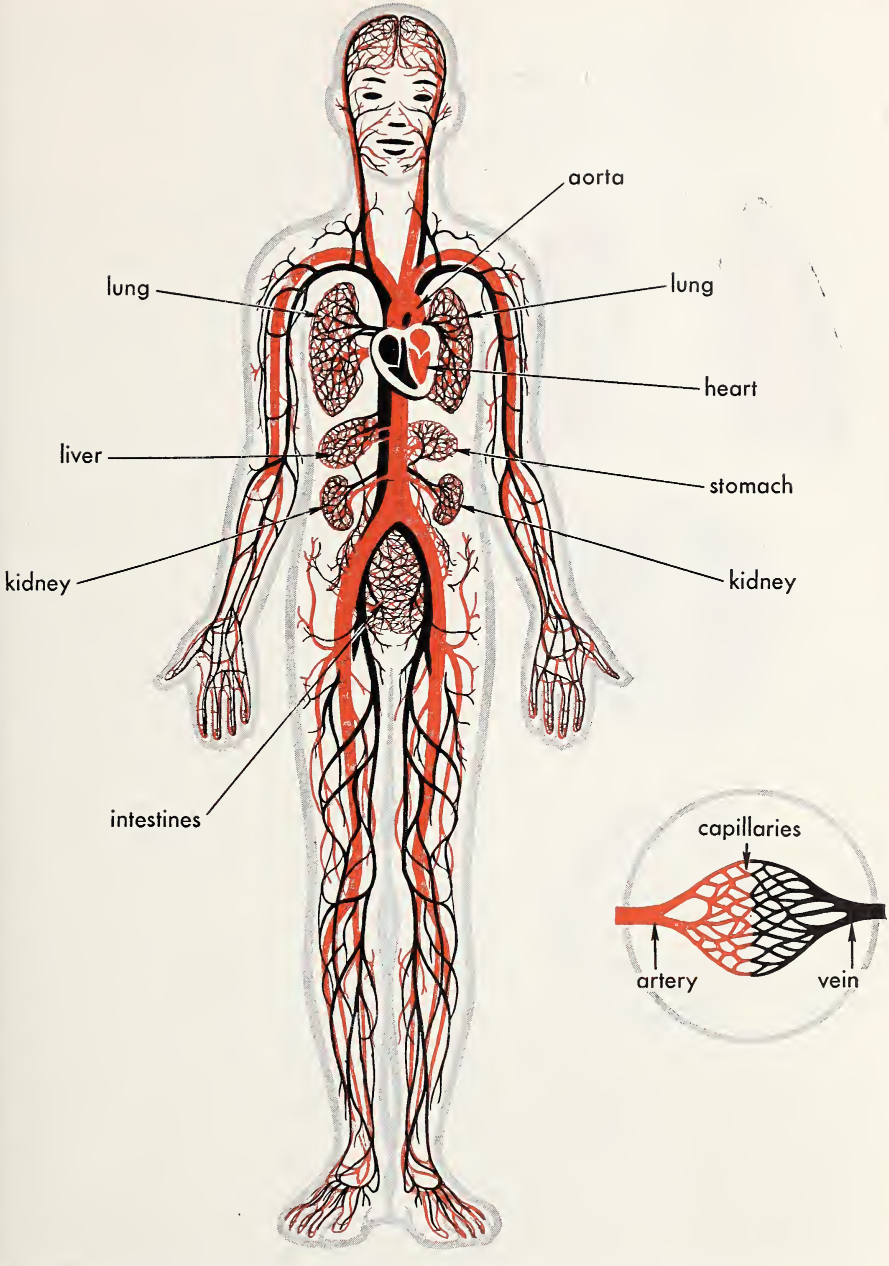
Now pull down the rubber sheet. This gives more room in the bell jar. The air inside the jar will then have more space. That means it will be at a lower pressure than the air outside. The greater air pressure outside will push air through the Y tubes into the balloons, and they will expand.

Push the rubber diaphragm up. What happens? Because the air pressure inside the bell jar is made greater than that outside, air is now pushed out of the Y tubes. The balloons collapse.

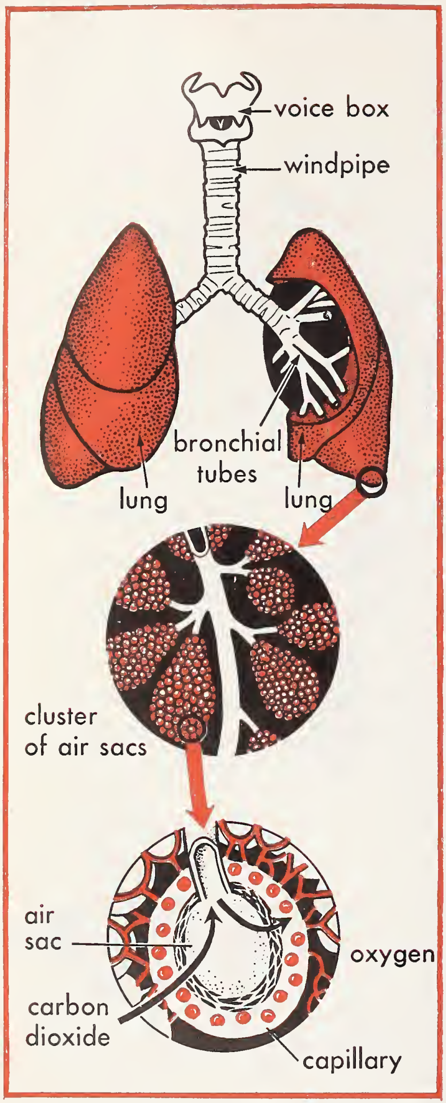
This model of what happens when you breathe is not perfect because the bell jar itself cannot expand. When air comes into your lungs the entire lung cavity expands, as well as the lungs themselves. When we inhale, our ribs, as well as the diaphragm, are pushed out. Hold your hands on your sides over your ribs and breathe deeply. Do you feel the ribs push outward?

As your lungs and chest cavity expand, the air pressure inside is lowered, and the greater outside pressure pushes air into the lungs. When you exhale, the chest cavity becomes smaller and the air pressure on the lungs makes them collapse slightly and push out some of the air.

Can you see by what you have just



32 How your blood circulates. Why does blood change color as it goes from an artery to a vein? (See insert.) Now trace a drop of blood from a vein in the left leg to an artery in the right leg; from the right hand to the left leg. Make a larger chart for your classroom.



33 Trace how air gets into the lungs, then into the air sacs, and finally how oxygen from the air enters the blood capillaries. What gas leaves the capillaries, finally to be exhaled by the lungs? (Adapted from drawing by Marion A. Cox from *Exploring Biology*, 4th edition, by Ella Thea Smith, courtesy Harcourt, Brace.)

done that it is the diaphragm and the chest muscles that "pull" air into the body and push it out?

From the Lungs to the Body Cells

What do you think your lungs look like? Look at Fig. 33. Your lungs contain millions of air sacs. If the air sacs of one lung were spread out, they would form a sheet which would cover the floor of a room 50 feet long and 22 feet wide.

Each air sac has a very thin wall covering it. You can get an idea of a group of air sacs if you think of a froth of soap bubbles. Each bubble is like an air sac. In your lungs each sac is surrounded by a network of capillaries.

Twenty per cent — one-fifth — of the air that enters these millions of lung air sacs is oxygen. Some of the oxygen goes rapidly through the thin cells lining the air sacs and then into the blood. At the same time, carbon dioxide leaves the blood and enters the air sacs. In this way, oxygen goes from the lungs into the blood. In this way, too, carbon dioxide goes from the blood into the lungs to be breathed out through the nose and mouth.

Thus your blood, which is mainly water, can dissolve and carry oxygen to the cells. But as you now know, it is the red blood corpuscles and their hemoglobin which really carry the oxygen. The hemoglobin gives up its oxygen when it reaches the cells of your body. Thus, as the blood in the arteries goes to the cells, it carries oxygen. This oxygen is what the cells use to burn or oxidize food. The blood in your veins, coming back to the lungs, carries carbon dioxide. This is

a waste product of oxidation. Veins also carry some of the oxygen that has not been used up.

Picture this: Your lungs take in air. The blood in your arteries carries the oxygen to your cells. The blood in your veins carries the carbon dioxide away from your cells. This carbon dioxide goes to the lungs.

THE CIRCULATING BLOOD

Would you like to see the capillaries in the web of a frog's foot, or in the tail of a small fish?

Use a net and moist hands (so as not to harm the fish) and place a small fish, such as a goldfish, on a flat piece of glass. To keep the gills moist, place a piece of wet absorbent cotton over the head of the fish. Now place the glass plate on the stage of the microscope. Be sure to cover the tail of the fish with a glass slide. Using the low power of the microscope, focus on the tail. Now observe carefully.

Do you see small round bodies moving in the blood vessels? These are the red blood cells which carry oxygen to all the other cells in the body. Notice how the smaller blood vessels join to form larger ones. You can also see the same thing in the webbed foot of the frog, or in the tail of a tadpole. You could see the same things in yourself if parts of your body were as transparent as the frog's webbed foot.

Many experiments have been made in the study of the circulation of blood in the bodies of animals. All these experiments tell us that in fish, amphibians (frogs, toads), reptiles (snakes, turtles), birds, and mammals (dogs, men), the blood circulates through a system of closed blood vessels.

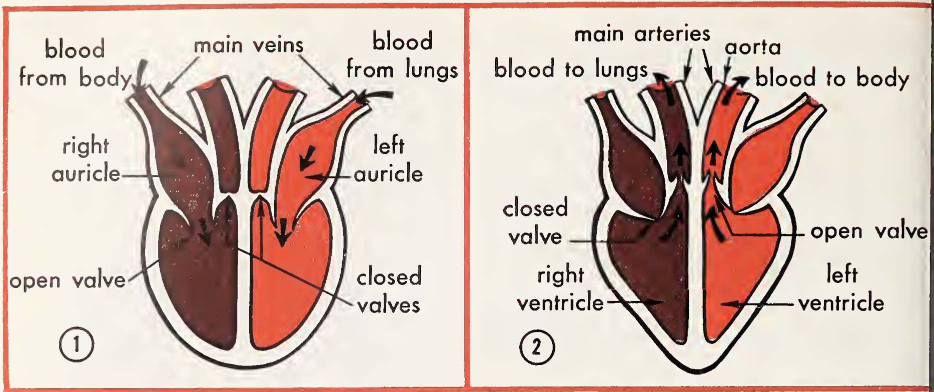
It takes about 45 seconds in an adult human being for the blood to circulate once around the body. An adult has about 5 to 6 quarts of blood in his body. Every 45 seconds, the entire 5 to 6 quarts circulate around the body. How much blood does your heart pump in 24 hours? Would you believe that in 24 hours, your heart pumps about 10,000 quarts of blood through your body? In that time, your blood circulates between 1,800 and 2,000 times. What kind of organ can your heart be that it can do so much work day after day, year after year? Let us see

THE HEART

It is hard to find an animal so transparent that you can examine its heartbeat under the microscope. But try the small water flea, Daphnia. You can find the Daphnia in almost any pond during early spring, summer, and autumn. It is about the size of a pinhead (Fig. 35). Place it under the microscope in a drop of water. You will see its small heart beating so quickly that you cannot count the beat. The heart of a Daphnia is very simple compared with yours.

One way to learn something about the structure of your heart is to cut apart a sheep's heart which you can get from a butcher. A sheep's heart is somewhat like yours. In fact, the hearts of all mammals are very much alike.

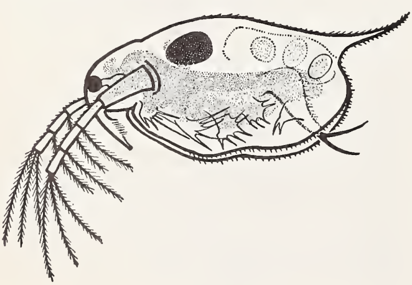
By cutting the sheep heart in half from the blood-vessel end to the tip, you can see a thick wall which separates the heart into left and right chambers (Fig. 34).



34 The heart's valves in action. *Left*, the heart gets blood from the body and lungs. *Right*, the heart sends blood to all parts of the body. Notice which valves are open and closed in the two drawings. If you can get a sheep's heart from your butcher, this drawing will help you find the valves.

The heart is somewhat like a house with two rooms upstairs and two rooms down. A trap door connects each upstairs room with the room below it. The heavy wall of muscle allows nothing to pass from the rooms on the right to the rooms on the left. And yet all your blood on its trip around your body passes through all four rooms in your heart. Let us see how this happens. Trace the path of the blood on Fig. 34 as you read on, and you will find out. As you do so, remember that these four "rooms" of the heart are made up of living tissue. The two lower rooms are made up of thick muscles.

35 A Daphnia, a small water flea. The large dark spot is the heart. *Experiment:* If you can collect some water fleas from a pond, study one under the microscope. Count the heart beat when the slide is cooled with an ice cube; when it is warmed by your hand.



The right side of the heart receives the blood from the body through a large vein which enters the *right auricle*. The right auricle is a thin-walled chamber at the top of the heart. It collects blood from the entire body. This blood is a dark maroon color because it has given up oxygen to the tissues in the body, and picked up wastes on the way back. One of these wastes is carbon dioxide, a gas you learned about earlier (p. 60).

From the auricle the blood passes through a valve into a thick-walled lower chamber called the *right ventricle*. If you examine Fig. 34, you will see that the valve closes to keep the blood from flowing backward into the right auricle. Then, as the heart muscle contracts, it pushes or squeezes

the blood out through a large artery going to the lungs.

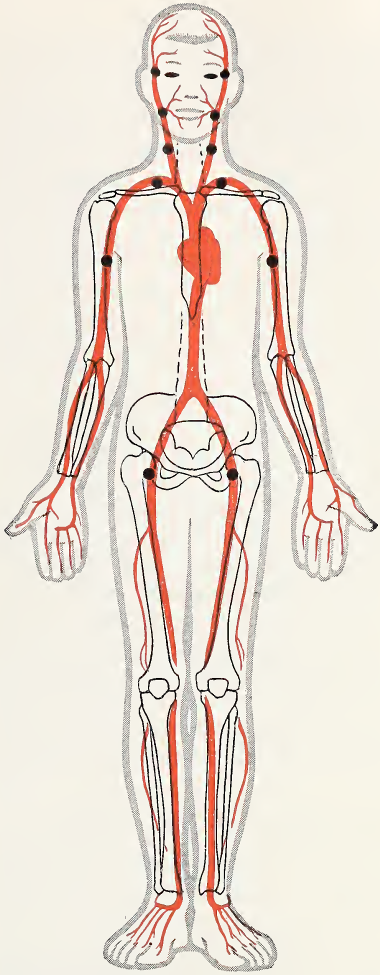
In the lungs the blood will lose carbon dioxide and gain oxygen. Now follow this bright red blood, loaded with oxygen, as it comes back through another vein to the heart. This time the blood enters the left side of the heart. It goes into the *left auricle*, then through the valve into the *left ventricle*. The valve between the auricle and the ventricle closes, and the heart squeezes the blood out through the open valve into the largest artery in the body, the aorta. From here the blood goes to all parts of the body, away from the heart through the arteries, back to the heart through the veins.

Arteries and Veins

Arteries and veins are not alike. If the arteries were tubes as stiff and solid as glass, you could not feel the pulsing of the blood. Get a piece of artery from your butcher. You will find that the walls of arteries are thick because they have an elastic tissue and muscles which expand and contract. This motion helps push the blood on through the blood vessels.

Feel the pulses in the arteries in your temple, neck, heel, arm, and wrist. Can you feel the blood vessels relax and contract?

It is because arteries expand and contract that a cut artery spurts blood. If you have had a course in First Aid, you have learned how to apply pressure at certain points to stop the flow of blood from an artery long enough for a clot to form. Suppose it was a slight cut near the surface. Show how pressure would be made with the fingers on a piece of sterile gauze placed over the cut. For



36 How many black dots are there? These are pressure points where an artery is near a bone. Pressing on the artery at these points stops bleeding from an injury beyond them away from the heart.

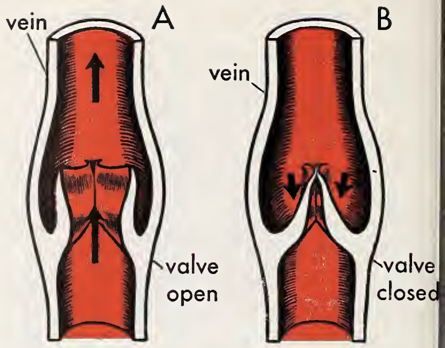
other cuts, you might have to exert pressure at a "pressure point" (Fig. 36) between the heart and the wound. A pressure point is a place where the artery is found near the surface of the

body. Usually arteries lie deep below the surface. But at these pressure points you can press the artery against a bone to shut off the blood supply. Study the latest manual on First Aid to learn how to stop bleeding. Of course, for any major cuts the doctor should be called at once.

Veins have less muscle and less elastic tissue than arteries. Their walls are thinner than artery walls. Therefore, when a vein is cut the blood does not spurt out. It flows more slowly and evenly. Since veins carry blood back to the heart against the force of gravity, they need something in them to keep the blood moving onward. Get a vein from your butcher and examine it. You will find valves which keep the blood from flowing backward (Fig. 37). One place to see a number of these veins is on the inside of your arm. Let your arm hang down, and keep clenching your fist. The small bumps that you see along the veins are the places where the valves are located.

Red, White, and Blue Blood

Have you heard of "red-blooded people" and "blue-bloods"? These expressions do not square with the facts. Every person's blood, no matter what the color of his skin, is bright red in the arteries and dark red or maroon in the veins. Blood is bright red in the arteries because these blood vessels carry red blood cells loaded with oxygen. Blood returning from the body through the veins has given up about 4 to 6 per cent of its oxygen and is a dark red color. Blood in the veins is also carrying carbon dioxide. It is only because we see our veins through the skin that they look blue.



37 How do your veins keep the blood from flowing backward? In *B*, do you see how the valves close as the blood flows back?

Some people also use the term "white blood." Have you ever had a skin blister on your hand from the rubbing of a tennis racket or baseball bat? The blister is filled with lymph, which is a colorless or whitish fluid. This fluid comes from the plasma of the blood. It filters through the walls of the capillaries as it is needed. As it filters through the walls, the blood cells and certain other parts of the blood are left behind in the capillaries.

Some part of every living cell of your body is in touch with lymph. Food substances and oxygen diffuse, or pass, through the walls of the capillaries into the lymph. From the lymph they diffuse into your cells. As the cells use the food and oxygen, waste products such as carbon dioxide are formed. These wastes diffuse out of the cells into the lymph and into the capillaries. Thus, lymph is a sort of "middleman" between your cells and capillaries.

There are only two veins in the body that carry bright red blood filled with oxygen. Do you know where they are? (See Fig. 32). Where does the blood pick up its oxygen? In the lungs. As you breathe

in, fresh air fills the thousands of tiny, thin-walled sacs at the ends of your lung tubes. Oxygen passes through their thin walls and then into the blood in the capillaries of the lungs. The two largest veins in the body then carry blood from the lungs to the left ventricle of the heart. These two veins which carry blood from the lungs to the heart have in them the reddest blood in the body.

THE BLOOD AND WASTES OF CELLS

Oxygen and food are not the only important things blood carries. By now you know that keeping healthy means keeping all your cells healthy. In order to do this (1) the cells must always have food and oxygen brought to them by the blood; (2) just as important, the chemical wastes which the cells give off must be taken away rapidly. Unless wastes are removed from your body, they quickly start to poison the cells, to upset their smooth working, and thus weaken the health of the entire body.

Removing Wastes

Not all the food you eat is digested. Whatever is not digested leaves the body through the large intestine and rectum (Fig. 29). This part of the food has never reached the cells.

As cells burn food and as they make protoplasm, they also produce wastes. One of these wastes from the cells, as you have just read, is carbon dioxide. But cells produce other wastes, especially when proteins are oxidized. Since protein has nitrogen in it, these wastes have nitrogen in them. They are often called *nitrogenous* (ny-TROJ-eh-nus) wastes. One of the most important of them is a substance called *urea* (yoo-REE-uh). Urea can poison the body cells if it is not removed.

We know that carbon dioxide and some water are removed through the lungs. How are other wastes removed?

Removing Wastes Through the Skin

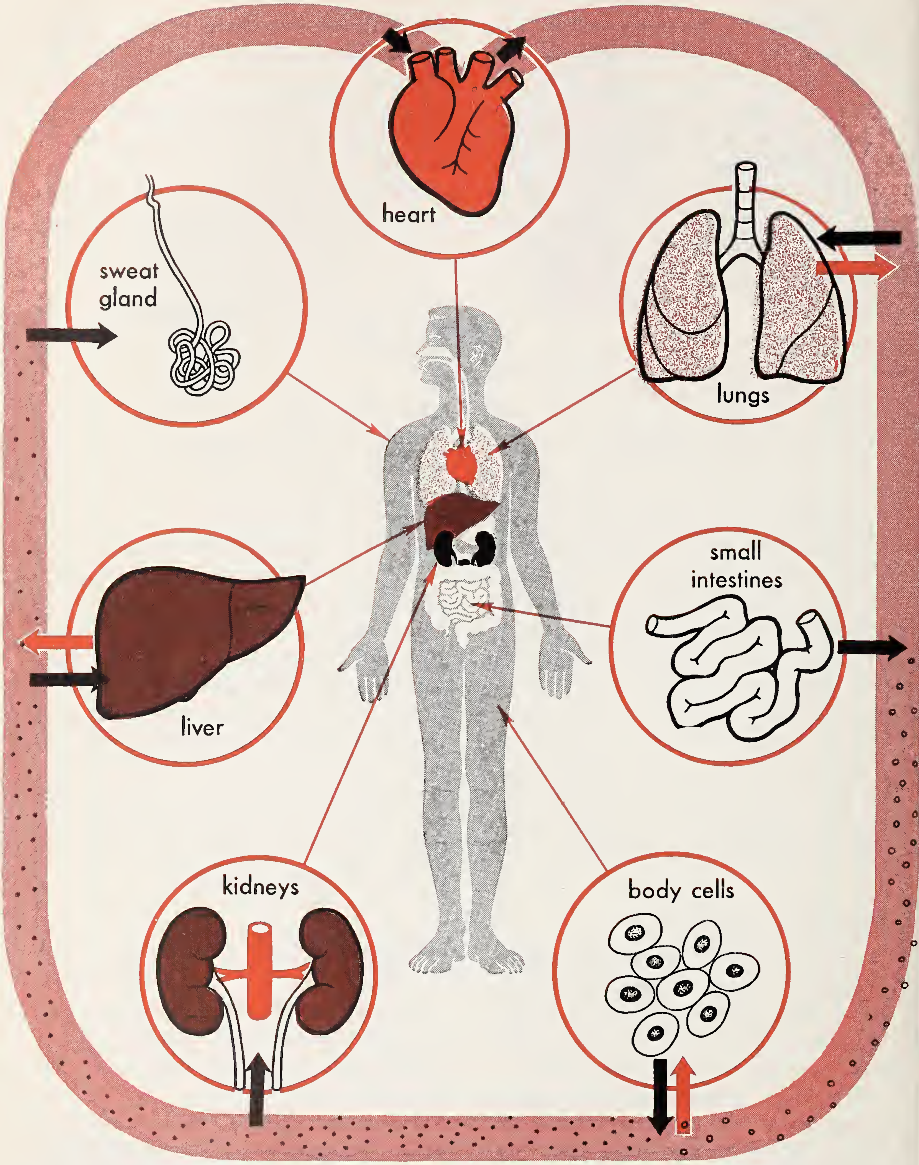
If you examine a piece of skin which has been prepared for study under the microscope, you can see how the skin is built for removing wastes. First, you will notice that the skin has sweat glands in it (Fig. 18). The sweat glands take some of the salts, urea, and water from the blood and send them out, or excrete them, from the skin. During heavy exercise you sweat freely. With the sweat you are getting rid of some waste substances through the sweat glands.

You can see that bathing helps to carry away from the surface of the skin the salts and urea, as well as substances which are the cause of body odors. Daily bathing is a very good aid to healthy living.

Removing Wastes Through the Kidneys

In addition to the lungs and skin, the two kidneys are organs whose main task is ridding the body of wastes.

Imagine a kidney bean about four inches long, and you have an idea of the size and shape of the kidney. A large artery enters and a vein leaves each kidney just where it is indented (Fig. 38). The blood in the artery brings to the kidney nitrogenous and



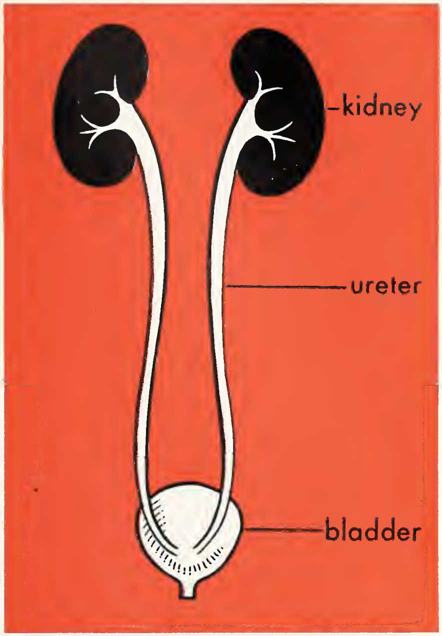
38 The blood stream brings every organ the material it needs; it also takes away wastes. At the lungs, the blood gives up carbon dioxide and takes on oxygen. At the intestines, the blood takes on food. For every cell, the blood gives up oxygen and food, and takes away carbon dioxide and other wastes. At the kidneys, the blood gives up liquid wastes. At the liver, the blood gives up its sugar to be stored. And the blood gets sugar from the liver as the body uses its sugar. The blood also gives up wastes at the sweat glands. Then it goes back to the heart.

other wastes. The blood in the vein leaving the kidney is free of these wastes. They have been left in the kidney. In the kidney, the wastes are filtered out through the walls of thousands of tiny tubes. Wastes are dissolved in water in the kidney and then sent, drop by drop, to the bladder. Finally, the wastes leave the body through a tube that leads to the outside. If you drink plenty of water each day — from 6 to 8 glasses — the kidneys and bladder can do their work easily. It is the blood, however, which carries the wastes to the kidneys, skin, and lungs.

Your Heart — Worth Caring For

Place your hand over your heart. Feel the beat of this remarkable organ, and recall how hard it must work for you. It is the center of a system of circulation which is a lifeline to every cell. It pumps blood with its food and oxygen to every cell. Its work enables the blood to carry away the wastes made by every cell to the lungs, skin, and kidneys.

Yet medical science has found that heart disease and other diseases of the circulatory system are the greatest killers of our time. Many people who have died of heart disease would be alive if they had had a physical examination once a year. In 1953, heart disease killed almost twice as many people over 40 years of age as did cancer. Doctors believe that many of these deaths were unnecessary.



39 The kidneys collect liquid wastes from the blood. Drop by drop these pass through the ureters (yoo-REE-terz) into the bladder. From there they leave the body.

Many think that the poor health practices which later injure the heart begin while people are young. Getting the right food, enough exercise, rest, and sleep will go a long way toward reducing some kinds of heart disease. Scientists need to learn still more about the causes and cures for diseases in the circulation of blood. In your lifetime, scientific discoveries may lengthen lives in this way. Perhaps you will be one to help with this research.

LOOKING BACK

Tool Words

Look up in the glossary any words in this list which you do not know. Then use the list to do the tests below.

absorption	antibodies	hormones
blood vessels — aorta, artery, vein, capillaries	bile	lymph
	digestion	nitrogenous wastes
parts of the heart — auricle, ventricle	enzyme	pepsin
	fibrinogen, fibrin	plasma
corpuscles	gastric juice, pancreatic juice, intestinal juice	villus (pl., villi)
red cells		lungs
white cells	hemoglobin	kidneys

Test Yourself

a. Write these headings in your notebook, leaving space for several words below each. Then copy from the word list above the words that belong under each heading. DO NOT MARK THIS BOOK.

1. Parts of the circulatory system
2. What is found in the blood
3. Digestive juices
4. Used in getting rid of wastes

b. In your notebook, complete each of the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. Digestion is . . . .
2. Absorption is . . . .
3. Digested food passes through the walls of the . . . .
4. The blood carries . . . and . . . to the cells of the body.
5. The smallest blood vessels are called . . . .

GOING FURTHER

In the Laboratory

1. (To be done only if school rules permit and you have your parents' consent.) To examine a drop of blood under the microscope, wipe the end of your finger with some absorbent cotton dipped in alcohol. Then prick your finger with a needle heated in a flame to kill the germs on it. After the drop of blood has dropped

onto the slide, wipe your finger with alcohol again. Put a cover slip over the drop of blood and examine the slide under the low- and high-power lenses. What can you see?

2. Place a frog in a jar which contains a piece of cotton soaked in ether. When the frog is relaxed, place it on a piece of cardboard. Cut a round hole the size of a quarter in one end of the cardboard. Over this hole stretch the web of the frog's foot and examine it under the microscope. Notice the small blood vessels. Can you see the blood cells circulating in the smallest vessels (Fig. 40)? You may also study plant cells and other animal cells under the microscope.

Put on Your Thinking Cap

1. Your heart pumps about 36,000 pounds of blood per day into your arteries. How many pounds is this per hour? per week?

2. Fish, reptiles, and amphibians are said to be cold-blooded animals; that is, the temperature of their blood is the same as that of their surroundings. Do you know of any animal groups that are warm-blooded?

Adding to Your Library

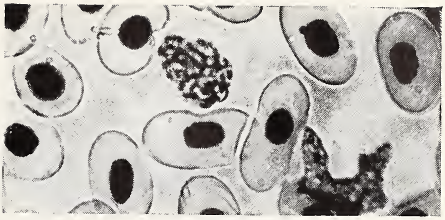
1. *Lifeline* by Leo Schneider, Harcourt, Brace, 1958. Be sure to read this simple story that explains how your circulatory system works.

2. *Wonders of the Human Body* by Anthony Ravielli, Viking, 1954. Here is an introduction to anatomy and the nervous and digestive systems.

3. *Your Wonderful Teeth* by G. Warren Schloat, Jr., Scribner, 1954. Two boys learn about teeth and how to care for them.

4. *You and Your Senses* by Leo Schneider, Harcourt, Brace, 1956.

5. *First Aid*, the official first-aid handbook of the Red Cross. It should be in your library.



GENERAL BIOLOGICAL SUPPLY HOUSE

40 Frog's red blood cells under the microscope. Each cell has a dark nucleus, surrounded by clear cytoplasm and a cell membrane.

A Bit of Research

1. Your body temperature is the temperature of your blood. Learn how to take your temperature with a fever thermometer. Then keep a five-day record of your temperature taken twice a day at the same times of day (possibly before breakfast and before dinner). Does your temperature vary? If so, how much? The normal body temperature for most people is 98.6° F. Was yours normal?

2. One of the more interesting pieces of research you can do is to find out about sleep. Do all animals sleep? How much sleep do adults need to keep the best health? How much sleep do young children need? Boys and girls your age? Old people?

Careers For You

Nurses are always in demand. There are not nearly enough nurses to serve in hospitals and private homes.

Pharmacists are trained to make up doctors' prescriptions at drugstores and in hospitals. Their work is important.

And, of course, *doctors* are needed in every city and town. Some are general practitioners, while others specialize in some line, such as surgery, diseases of the eye, heart disease, or children's diseases.

Laboratory technicians are needed to do blood counts, to make chemical tests of blood, and to do many like services.

CHAPTER 5

Your Body Against Unseen Killers

Around you are unseen killers — germs. Are you lost? Not at all. Man, working as a scientist, has learned to kill germs. Your body protects itself and is protected by people working with you and for you.

LET US GO back about one hundred years. In one town dozens of men, women, and children have been struck down by a deadly disease called smallpox. Many of its victims die within a few days. Those who get well are scarred for life. Strong and weak alike are victims. No medicine known stops the deadly smallpox.

In another town there is an epidemic of typhoid fever. Where did this killer come from? Person after person dies from the disease, but no one can stop its deadly work.

Diphtheria and pneumonia are also killers that are claiming other victims in one village after another. Why can't these killers be stopped?

Here and there, as years went by, doctors began to gather facts that seemed to point to the killers. And what did they find out? They found that the real killers were so tiny that they could not be seen with the naked eye. They were unseen killers. But some of them could be seen through a microscope. One scientist after another discovered that these killers

were disease *germs*. Germs had been causing many of the diseases from which thousands of people had died.

These silent killers have killed more children and adults than any other killers in history. In the year 1600 — over 350 years ago — the different plagues caused by germs then unknown killed many children. Thousands upon thousands of babies and children died in the 1600's because living conditions allowed disease germs to multiply rapidly. Many children did not reach the age at which boys and girls now are graduated from high school. Compare this short life with a life expectancy of some 68 years, our average life span in the United States today. What has caused this increase in the length of life? Part of the story begins with a Frenchman.

Louis Pasteur, a French scientist who lived about 100 years ago, began the battle against disease by trying to find out what was killing the silkworms in France. He found that they were being killed by tiny living things called germs. After experiments Pasteur wrote that he thought most diseases were caused by germs. After Pasteur had made his idea widely known, one scientist after another began to experiment. Robert Koch, a German, discovered how to grow the germs of tuberculosis on food jelly. He and other scientists learned how to stain them with dyes so the germs could be seen under the microscope.

Since the time of Pasteur and Koch, many discoveries have been made. We are now able to save the lives of thousands of persons who would have been killed by germ diseases. For instance, in 1953, there were only sixteen cases of smallpox in the United States. Make no mistake: germs are just as deadly as ever, but we have learned (1) how to keep germs out of the body; (2) how to keep them from multiplying so fast; and (3) how to destroy them if they should enter the body.

Knowing how to ward off germ-caused illnesses makes us fear them less. It is your job, as it is of every wise person, to get this knowledge which scientists have discovered.

STUDYING THE UNSEEN

Let us begin by experimenting to see where germs can be found.

Take six Petri dishes filled with nutrient gelatin, on which bacteria can grow. Sterilize the dishes in a steam pressure chamber so that nothing can possibly remain alive in them.[1] After the dishes have been sterilized and cooled, use three of them as follows. For the first dish, take a wire loop which has been heated red-hot in a Bunsen flame. This heating will kill anything alive on the loop. As soon as it cools, put the loop in a drop of water from the faucet and brush the surface of the gelatin, making a figure 8 on the gelatin. Put back the cover at once. In the second dish press your fingers gently on the gelatin. Place a hair from your head on the third. Put back the covers.

Leave three sterilized Petri dishes untouched and unopened. They will be the controls which you must have with each experiment.

[1] Your teacher should be there to show you how to use the sterilizer. If a sterilizer is not available, place the dishes in a pressure cooker for one hour.

MILES LABORATORIES

41 Those white and gray splotches you see on the round Petri dish are colonies of bacteria. Each colony is made up of millions upon millions of bacteria growing on the foodstuff in the dish.

Put all six Petri dishes in a warm, dark place and leave them there for two days.

When you examine the first three Petri dishes at the end of two days, you will see whitish spots on the gelatin which certainly were not there two days before. This will show that there were germs in the water, on your fingers, and on your hair. The control dishes are clear; there are no growths on them. Why?

Kinds of Bacteria

To examine the growths in the Petri dishes you will need the wire loop, a microscope, some slides, and a stain, such as methylene blue. Using the wire loop, take a bit of the material from the white spots on the gelatin. Smear it on a slide. Pass the slide slowly through a low flame four or five times and then stain the material with the dye.

Under the highest power of the microscope, you may find different kinds of organisms. If you do find them, most of them will probably be *bacteria* (sing., *bacterium*). There are three types of bacteria. Some are rod-shaped, called *bacilli* (buh-SIL-eye) (Fig. 42, top). Some are spherical, like tiny marbles, and are called *cocci* (KOK-si) (Fig. 42, center). Some are spiral-shaped, like coiled springs, and are called *spirilla* (spy-RIL-luh) (Fig. 42, bottom).

The large spots you see in the Petri dishes are made up of many colonies of bacilli, cocci, or spirilla. These three types of organisms are bacteria, as you have just read. But — and this may surprise you — bacteria are plants. They must get their food from other plants and animals or from dead material. Since bacteria live and feed on other organisms, they can cause disease.

Even with your best microscope, you will not be able to see certain very small organisms called *viruses* (VY-rus-ehz). These can be seen only with the electron microscope (p. 100). Viruses cause such diseases as smallpox, yellow fever, measles, infantile paralysis, and influenza. Viruses, it is now thought, also cause the common cold.

Scientists do not agree completely on what viruses really are, but most scientists think that they are large molecules of protein.

Naming Microbes

Microscopic organisms are called by many names. They are called *micro-organisms* or *microbes* because they are small (micro) organisms. They are also called germs. We shall use the word *germs* to mean microbes

that cause disease. Viruses, which cannot be seen under the ordinary microscope, are also micro-organisms.

Besides the bacteria, which are plants, there are also the *protozoa* (proh-toh-ZOH-uh), which are single-celled animals.

Some protozoa cause disease. Protozoa, like the common fresh-water ameba and the paramecium, live in ponds or streams and cause no diseases. But certain other protozoa cause malaria, sleeping sickness, and other diseases.

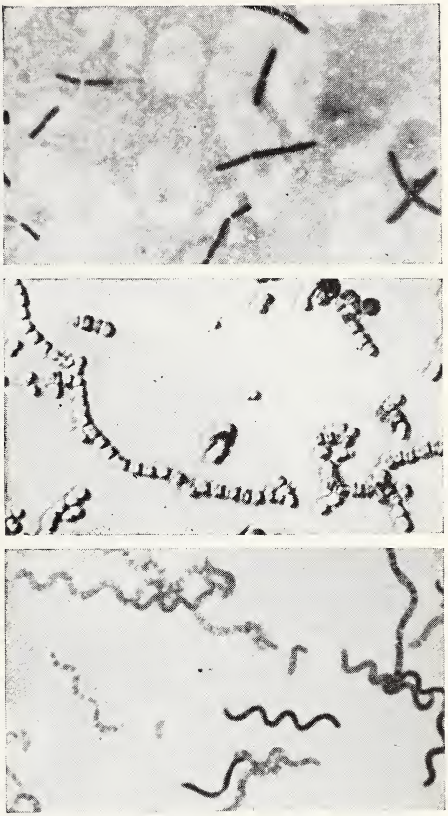
Bacteria Can Protect Themselves

Bacteria can live in a resting stage. In this stage they are called *spores*. When a bacterium forms a spore, it grows a thick wall which protects it. Under favorable conditions — that is, where there is warmth, darkness, moisture, and plenty of food — the bacterium breaks through the spore wall and begins to multiply in number.

Scientists have found spores of bacteria in the air, even fifteen miles up and more, and in hot springs, on ice, on dry dust, and in many places where most living things would die. Their thick wall allows the spores to stay alive under very unfavorable conditions.

Your Defenses Against Bacteria

Bacteria do multiply rapidly. A bacterium, given warmth, food, moisture, and darkness, may divide into two bacteria every 15 minutes. At the end of 15 minutes there will be 2; at 30 minutes, there will be 4; at 45 minutes, 8; and at the end of 8 hours, more than 4 billion!



MILES LABORATORIES AND GENERAL BIOLOGICAL SUPPLY HOUSE

42 Through the microscope, the three types of bacteria. *Top*, rod-shaped bacteria, bacilli. *Center*, spherical bacteria, cocci, in chains. *Bottom*, spiral-shaped bacteria, spirilla.

Although bacteria increase their numbers amazingly, you are well protected because:

1. Most bacteria are either harmless or useful.

2. Your body protects itself from harmful bacteria.

3. Your body can be helped to overcome bacteria which cause disease.

4. Your community stands watch

night and day to protect you from disease. (In the next chapter you will read of many ways your community helps you to conquer bacteria.)

5. You can learn how to ward off harmful bacteria and so keep them out of your body.

Useful Bacteria

Perhaps you were surprised to read that most bacteria are harmless or useful. This is true. You will read in the chapter entitled "Better Food from Better Soil" how certain bacteria add useful chemicals to the soil. One important group of bacteria, called *decay* bacteria, helps to keep our world fit to live in. They do it by breaking down dead material so that other living things can use it. For instance, they work on a dead tree until it becomes part of the soil. The tree decays only because decay bacteria and other living things use part of it for food. Just think what this world would be like if dead plants and animals never decayed!

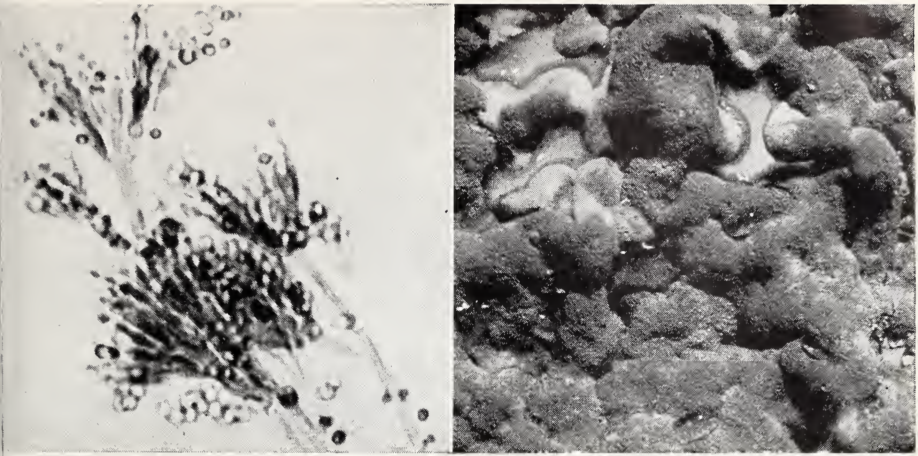
Certain kinds of decay bacteria are useful in curing cheese, tobacco, and leather, and in preparing flax, from which linen is made. In the making of flax, bacteria cause the decay of the body of the flax plant, leaving the fibers.

Microbe Against Microbe

Have you ever put under the microscope some of the blue-green mold that you have found growing on an orange, on cheese, or on bread? Prepare a slide of this mold and look at it under the highest-power lens. This

TABLE 3 Some Enemies Among the Microbes

Disease	*Microbe*	*Destroying the Germ or Its Products*
Cold	Virus	As yet unsuccessful
Smallpox	Virus	Antibodies produced by vaccination
Infantile paralysis	Virus	As yet unknown
Yellow fever	Virus	Antibodies through injection
Tuberculosis	Tuberculosis bacillus	Streptomycin (not always successful)
Pneumonia	Pneumococcus	Sulfa drugs Penicillin Antibodies in plasma
Typhoid fever	Typhoid bacillus	Antibodies produced by inoculation
Diphtheria	Diphtheria bacillus	Antibodies (antitoxin) produced by inoculation
Tetanus	Tetanus bacillus	Antibodies (antitoxin) produced by inoculation
Malaria	Plasmodium (a protozoon)	Atebrin Quinine
Sleeping sickness	Trypanosoma (trip-an-oh-SOH-mah) (a protozoon found in Africa)	Arsenicals (ar-SEN-ih-k'lz)



ELI LILLY AND CO., AND E. R. SQUIBB AND SONS

43 *Left*, the Penicillium fungus (blue mold) under the microscope. It has a branching thread-like body. *Right*, millions upon millions of Penicillium fungus plants growing in a large vat. The clear droplets have in them the penicillin the mold makes.

mold is a tiny plant called *Penicillium* (Fig. 43).

Dr. Alexander Fleming noticed this bluish growth when he was looking at a culture of bacteria. He noticed that the bacteria which he had expected to find in the culture were missing in the area around the Penicillium. Had the Penicillium (Fig. 43) made a substance which had killed bacteria? Yes, it seemed to be so. Then other scientists in England set up a series of experiments to test this theory. They found that Dr. Fleming's discovery was true. They discovered that the mold produced a powerful germ-killer, which we now call *penicillin* (pen-ih-SIL-in).

In *Medicine on the March* (see "Going Further") you can read the story of how penicillin was produced in amounts great enough to help in curing millions of sick persons every year. Penicillin is used to check many kinds of infection caused by bacteria. Any germ-killer made by a living organism (Penicillium mold is a plant) is called an *antibiotic* (an-tee-by-OT-ik).

Penicillin is not the only germ-killer made by microscopic plants. We now have *streptomycin* (strep-toh-MY-sin) (Fig. 44), discovered by Dr. Selman Waksman of Rutgers University in 1945. Streptomycin is used very successfully in certain types of tuberculosis. *Aureomycin* (or-ih-oh-MY-sin) and other antibiotics have also been produced by soil bacteria.

These are by no means all our allies among the micro-organisms. No doubt many more are still to be discovered. Watch your science magazines for the latest discoveries. Perhaps, in your later years, you will discover one of these allies.

KEEPING GERMS OUT OF THE BODY

Germs that are kept outside your body can do you very little harm, but

E. R. SQUIBB AND SONS

44 This doesn't look like much, does it? Yet this is the fungus which makes streptomycin, a drug used against tuberculosis.

the question is, how do germs get into your body? There is one answer to this question: germs enter through openings in the body. Let us see what this means.

Entry with Water, Milk, or Food

Typhoid germs usually enter the body in water or milk. They may be carried for years by a person who is not himself sick with typhoid. Such a person, called a typhoid carrier, may spread the germs through the water or milk you drink. Tuberculosis germs may also enter with milk.

Bacteria can enter our bodies with the food we eat. The housefly is a carrier of germs. Flies feed on garbage and filth and breed there. Then, with their feet covered with germs, they may fly to the food in your kitchen — that is, if they can get in. Also, food that is not kept cold in hot weather allows harmful bacteria to grow.

What can you do to keep germs from entering your body with milk, water, and food? You can do much. You can buy foods from stores that are kept clean. You can make sure that flies are kept away from all foods in your home. You can try to keep food from spoiling. You can make sure that your hands and dishes are kept very clean. When on a camping trip you can make sure that you drink water only from a stream or spring that has been declared safe. You can look for the label on milk that will tell you it has been *pasteurized* (PASS-ter-yzed) (see next chapter). In other words, you can help make sure that you eat or drink nothing that may have harmful bacteria in it.

You can do part of this work yourself, but your community has to do the rest. In the next chapter you will read what communities can do when they work together to keep germs out of milk, water, and food.

Entry with Air

Some of the bacteria which cause diseases of lungs and throats are believed to enter our bodies with the air we breathe. Diphtheria is caused by a bacillus which lives in the throat where it makes a poison or *toxin.* The tuberculosis bacillus at times may enter with the air and lodge in the lungs. The pneumonia coccus affects the lungs and bronchial tubes. These three bacteria can be spread, therefore, by sneezing and spitting. They may be carried to another person in the droplets from sneezes and coughs.

Other diseases which are spread through the air are influenza and the common cold. These diseases are caused by viruses, not by bacteria.

It is easy enough to see what you can do to prevent the spread of diseases by air. Whether or not you have a cold, be sure to cover your nose and mouth with a handkerchief when you sneeze or cough. If you can avoid it, don't get close enough to another person to let your breath carry the cold virus to him. In an influenza epidemic, stay out of crowds.

Scientists have not found a cure for the common cold. Colds make people lose more school days and working hours than does any other ailment. How much school time did you lose last year from colds?

The best advice to you when you do catch a cold is to rest, eat lightly, drink liquids, and keep warm. Scientists have found, however, that keeping the body in good general health helps you withstand colds. Plenty of vitamin D, the vitamin found in cod liver oil and produced in your skin when you are out in the sunshine, helps to build resistance to colds.

Entry Through the Skin

Of course, a cut or break in the skin will allow bacteria to enter your body. The tetanus or lockjaw bacillus enters this way. The tetanus germ lives in the ground. It cannot grow in air, but it can and does grow in a wound caused by stepping on a nail. Exploding firecrackers or sharp knives cause deep wounds, in which tetanus germs can find a place to grow. If you get such a wound, it should be cleaned with an antiseptic at once. You should see a doctor at once if the wound is deep. If he thinks there is danger of tetanus infection, he will give you the proper treatment.

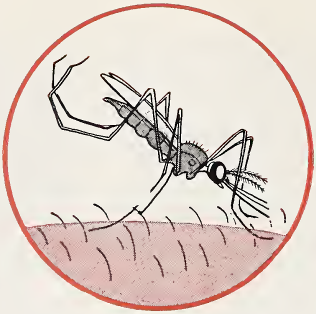
What can you do to keep bacteria from entering breaks in the skin? You can take care of even the slightest cut at once.

One of the common ways certain bacteria, protozoa, and viruses enter the body is through insect bites. For instance, the germ which causes typhus enters the body through the bite of the body louse. Soldiers (during wartime) often are hosts to body lice because of the unsanitary places they may have to be in. During World War II (when soldiers could not bathe often enough to get rid of insects), DDT was sprayed on their clothing and bodies to kill the lice.

Malaria, which causes more illness and death than any other germ disease, is carried by the malaria mosquito. This is not the common mosquito of the cooler climates, but the *anopheles* (an-OFF-uh-leez) mosquito (Fig. 45). Anopheles mosquitoes are sometimes found in the United States in fairly large numbers even as far north as Ohio. Study Fig. 45 to learn how you can tell the common, harmless mosquito from the anopheles.

To protect yourself from mosquitoes and flies, put up your screens early. You can paint screens with a DDT solution which will kill many of these harmful insects. Then make a survey of your yard to drain any pools of water where mosquitoes might breed. Oil spread on the surface of standing pools of water will kill the larvae of mosquitoes. The larvae breathe at the water's surface. Can you tell why oil would kill them?

Some germs do not need to get through the skin to cause trouble. Athlete's foot is caused by a fungus plant that grows on the surface of the skin. The fungus of athlete's foot is



45 The common mosquito on the left; the anopheles which carries malaria, on the right. What is one difference between the two insects?

found on floors of places like locker rooms and swimming pools. This fungus generally feeds on the skin on the bottom of the feet and between the toes where it causes great itching and sores. Therefore, when you go to public swimming pools, wear rubber bathing slippers. It would be wise to give your own bathroom floor a wash with chlorine water every week or so.

Infantile Paralysis (Polio)

You can see that it would be difficult to prevent a germ disease if you did not know how the germs got into your body. Infantile paralysis (polio) is such a disease. Scientists think that the viruses of polio enter the body through the mouth, nose, or throat, but they are not absolutely sure. They do not know whether polio viruses are waterborne or airborne, or whether they enter with food. Although cases appear many months during the year, the warm summer months seem to be the time when the virus is most active. You have read about the vaccine prepared by Dr. Jonas E. Salk and given experimentally in 1954 to a large number of children in the hope that a way had been found to prevent polio. Carefully-kept records of the results showed the vaccine to be highly effective. Today there are far fewer cases of polio, and the vaccine is available to anyone who wishes it. But the work still goes on to wipe out polio completely.

Symptoms of Illness

A trained expert can usually tell what an illness is by the symptoms. A symptom is a clue, or a sign, but the puzzling thing is that many illnesses show the same symptoms in the beginning. A fever, a sore throat, and a cough may be the first signs of any one of three or four diseases. Therefore, you should always tell your parents when you feel ill, and remember that a doctor is trained to read your symptoms and treat the illness. Do not try to treat it yourself.

BODY DEFENSES AGAINST DISEASE

You know now how germs enter your body. In your experiments with bacteria, you have found that they are everywhere. Does that mean that you are at their mercy? Not at all, not even if they do get into your body. Your body has several lines of defense to do battle with them.

First Line of Defense

Earlier in this unit you learned that flat cells like those on the inside of your cheek cover the entire surface of your body. Your skin consists of several layers of flat cells. These cells are your first line of defense against bacteria. Bacteria cannot get through a whole skin.

Bacteria get into your mouth, but they cannot easily get into the body tissues. First, there are protecting cells which cover the inside of your gullet, stomach, and intestines. Second, these inner cells lining the food tube and organs of digestion, as well as your nose and throat, make a sticky fluid called mucus. In fact, we call these linings *mucous membranes.* The sticky surface of these mucous membranes catches many bacteria and helps to kill some of them. Third, if the bacteria reach your stomach, the acid in the gastric juice will also kill some of them. But sometimes more bacteria enter than the mucous membranes or the gastric juice can take care of. Then we must depend upon other defenses.

It is important to keep the layer of covering cells unbroken. But how can an active boy or girl of your age do that? Many times you bruise or cut yourself in games or on hikes. If you get a bruise, or a cut in which the skin is broken, you will have to make some kind of covering for it. First, wash the cut with soap and water. If the cut is small, you may use a Band-aid; if it is large, a loose bandage may be put on until a clot forms. The clot closes the break in the skin. (*Caution:* A tight bandage may stop repair of cells by keeping air from the wound and by cutting down blood circulation.)

Second Line of Defense

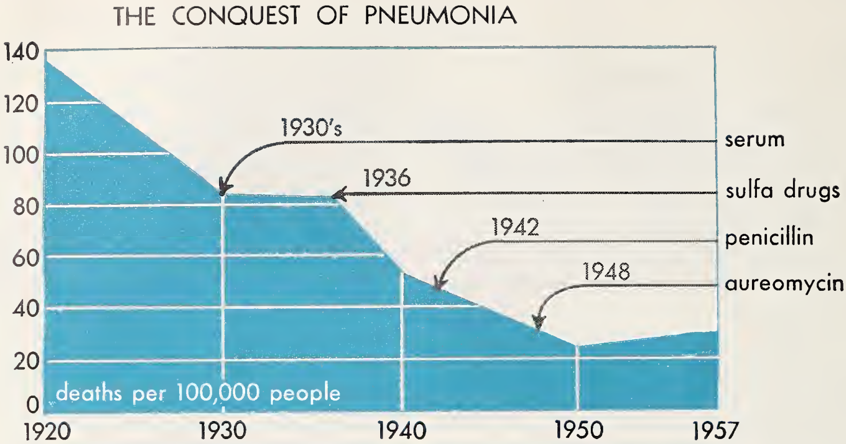
Suppose you did not cover a cut in time. What might happen? Bacteria might get in and multiply. The area around the cut would then throb and swell and show redness. Pus would form. Pus shows that your second line of defense is at work. If you were to examine a sample of pus under the microscope you would find that it has dead bacteria in it and many living and dead white blood cells. Why are there so many white cells in pus?

From your earlier reading, you know that the white cells increase in number whenever there is infection in the body. Great numbers of white cells rush to the spot and attack the bacteria. White cells surround bacteria and kill them. When they have destroyed many bacteria, these white cells die and new ones take their place.

Sometimes, however, germs enter the body in such large numbers or multiply so fast that even the white cells cannot conquer them. This might happen if a person caught smallpox or typhoid. But we have other defenses besides the white blood cells. Let us see what they are.

Other Defenses in the Body

Do you have a vaccination scar on your arm or leg? The scar shows that you have been protected against smallpox. It shows that the vaccination "took." You will not get smallpox within four to eight years after you have been vaccinated successfully, no matter how many times the smallpox virus enters your body. In *vaccination* against smallpox, a small amount of the virus of cowpox is placed in a small scratch on your



46 The line dropped each time a new drug was found for the treatment of pneumonia. How many people per 100,000 died of pneumonia in 1920? in 1950?

arm.[1] Your body then brings up its defenses against this virus, by making antibodies. Antibodies are chemicals made by the body; antibodies destroy germs and viruses. These antibodies stay in the blood plasma six to eight years and destroy any smallpox virus that may enter the body. Scientists say you are then *immune* to the disease. But this *immunity* does not last all your life. If someone in your city or town should get smallpox, most people would have to be vaccinated again.

You cannot be made immune to typhoid fever, diphtheria, yellow fever, or cholera by vaccination. Instead, dead or weakened bacteria or viruses (gotten from animals like the cow) are injected into the body. This injection is known as an *inoculation* (in-ok-yoo-LAY-shun). The body then makes antibodies against these organisms. You have probably been inoculated for diphtheria. If so, you have the antibodies for diphtheria in your blood. Antibodies for some diseases do not remain in the body for more than a year; others may last a very long time. During World War II, soldiers were inoculated against many diseases. Travelers to foreign countries must be vaccinated against smallpox. Usually they are also inoculated against typhoid and yellow fever.

[1] Cowpox is a disease of cows; it is caused by a virus very similar to that which causes smallpox.

Natural and Acquired Immunity

When you are vaccinated or inoculated against a disease, you really get a slight attack of the disease. This attack causes your system to make antibodies and thus protects you against a real attack of the disease. When a person has certain diseases, such as chicken pox and whooping cough, his body builds antibodies. For instance, an attack of typhoid fever usually makes a person immune for life. This is true also of some children's diseases, such as chicken pox. During the disease, the body makes

antibodies which prevent future attacks.

There are two ways, then, of getting immunity to some diseases:

1. By building antibodies in the blood stream by vaccination or inoculation.

2. By having certain diseases and recovering from them.

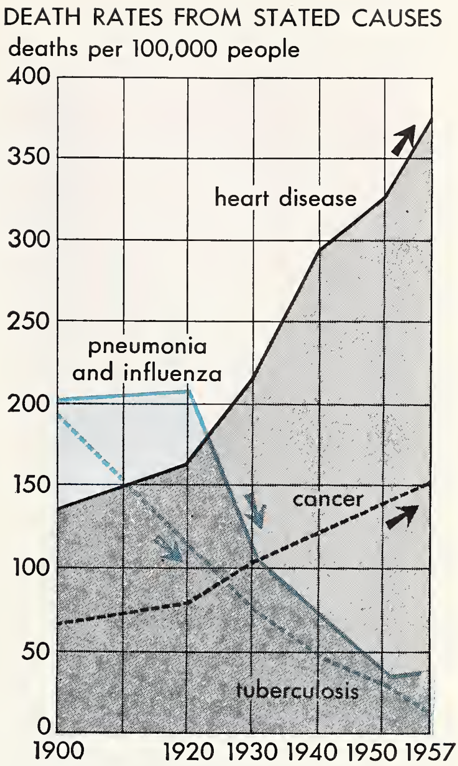
On the other hand, some people are born with immunity to certain diseases. We say that they have a *natural immunity*. They probably had antibodies for these diseases when they were born.

Help from Animals

There is still another way of fighting certain diseases. Scientists have discovered that antibodies produced in other animals can be injected into our bodies.

As you have read, the bacteria which cause some diseases stay in one place in our bodies and produce poisons or *toxins*. Diphtheria germs stay in the throat; tetanus germs, in a wound. If the bacteria of diphtheria or tetanus are injected into a horse, for example, the horse will produce in his blood the chemicals to act against the toxin. These chemicals are called antitoxins. An *antitoxin* acts against a toxin and makes it harmless. These antitoxins are to be found in the plasma of the horse. The plasma is taken from the horse and stored in vials.

When a person is ill with tetanus or diphtheria, the antitoxin can be injected to act against the toxin of the disease. Thus the animal which makes the antitoxin has helped to cure a person. Many lives have been saved by the antibodies and antitoxins produced in horses, sheep, rabbits, and

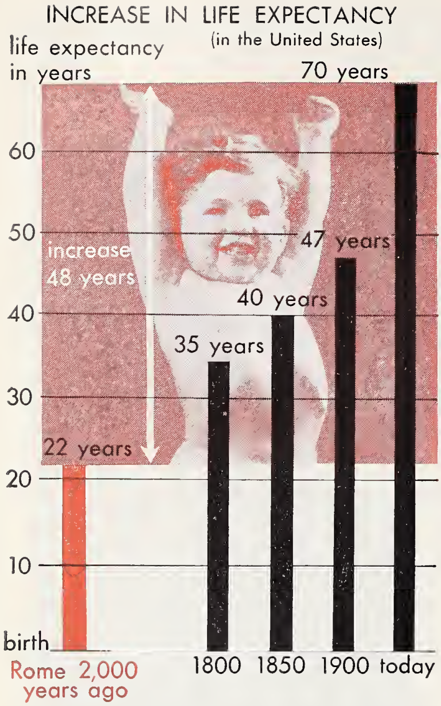


47 What three diseases are on the downswing? Which two are on the upswing? According to the graph, which disease killed more people in 1920 — pneumonia or heart disease? In 1942, which was the greater killer? Why?

guinea pigs. These animals are in the service of mankind.

Chemicals Against Microbes

For some diseases we must have other chemical help. Here, again, scientists have come to our aid. You have used iodine to destroy bacteria. Perhaps you know that chlorine is used to kill germs in drinking water. Chlorine will also kill the fungus of athlete's foot. Quinine and *atebrin*



48 How your life span has increased. How many years have been gained for man in the past one hundred years? In the past sixty years?

(AT-uh-brin) are used against malaria. The sulfa drugs are used in the battle against germs that cause certain types of pneumonia.

The list of chemical cures is a long one. New ones are constantly being discovered. Discoveries of this kind show how science helps to increase man's life span. Perhaps you will help make such a discovery.

Cancer — Cause Unknown

Finding the cause of any disease is a big job for scientists. Today scientists are still searching for the causes of such diseases as cancer, arthritis, and high blood pressure. These diseases may not be caused by germs.

Although Louis Pasteur showed that germs cause many diseases, it is now a widely accepted theory that cancer is not caused by a germ. In cancer, certain cells which ordinarily do not divide begin to divide rapidly in a wild manner. Then they form a shapeless lump, or cancer, somewhere inside or on the surface of the body. During their growth, these wild cells may interfere with the normal working of the organs of the body. Finally, parts of certain types of cancers may get into the blood stream and form cancers elsewhere in the body.

Experiments on animals have shown that constant irritation on parts of the body may be the cause of one kind of cancer. Very little is known about what causes cancer of the inner organs.

Careful study of cancer in animals and humans has shown that there are many signs of its development. Here are a few of these signs:

1. A growth (pimple or mole or hard lump) which does not disappear and often gets larger.

2. Signs of constant constipation; that is, poor bowel movement in a person who has had regular bowel movement.

3. Any *unusual* discomfort or discharge (colorless or tinged with blood) in any part of the body.

These signs may not mean cancer at all, but it is wise to let the doctor check them.

Cancer in its early stages can often be treated successfully. X-ray treatments or surgery can often cure a cancer at its beginning. Recently scientists have been working to find very simple ways of discovering cer-

tain kinds of cancer. Even now there are ways a doctor may discover certain types of cancer through examination. Early discovery of a cancer means that it probably can be treated successfully.

However, there is much work to be done in finding the cause and treatment of cancer.

Diseases Not Caused by Germs

There are other diseases which are not caused by germs. Diabetes is caused by a lack of the substance *insulin* (IN-suh-lin). This chemical — a hormone (p. 82) — is made by the pancreas. Insulin, like other hormones, is sent directly into the blood. Diabetes results when the pancreas does not make enough insulin.

Insulin helps the body to oxidize sugars and fats. Without insulin, therefore, the body cannot oxidize all the sugar it gets in food. As a result, sugar is found in the urine of diabetic people. Since the discoveries made by Dr. Frederick Banting of Toronto, and others, diabetes can be treated by careful diet and by daily injections of insulin. Before the discovery of insulin, a diabetic person could not use enough of the sugar in his body to give him the energy he needed for his daily work.

Other diseases which are probably not caused by germs are high blood pressure and certain kinds of heart disease. One cause of high blood pressure is the narrowing of the small arteries. The heart, therefore, has to pump harder. That is, it has to work harder, get up a higher pressure, to send the blood through narrower arteries. No sure cause or cure for high blood pressure has been found. But doctors advise us that rest and careful living keep down high blood pressure. Worry also seems to make the arteries narrower. So it would seem that keeping from worrying would keep blood pressure down.

As the body grows older, changes take place in the circulatory system. In some people, the soft walls of the arteries harden because certain minerals of calcium are deposited in them. This is known as hardening of the arteries. Hardened arteries are less elastic. They do not stretch easily when blood flows through them. Therefore, the heart has to pump harder to force the blood through the body. This extra work puts a strain on the heart.

Many of these diseases not caused by germs are diseases of older people. Are you wondering why you should study about them? Sometimes, perhaps, they would not have shown up in old age if the person had taken better care of his health when he was young. There is another reason why you should know about these diseases, such as high blood pressure, heart disease, and arthritis, that come with the wearing out of the body. It will be the scientists of your generation — perhaps you will be one of them — who will probably find out how to treat these diseases.

Tuberculosis — Arrested, But Not Cured

Another disease for which we need a cure is tuberculosis. It is caused by a germ that may strike young or old, weak or strong. It is more likely to develop in young people, however, and in persons who are run-down physically. People in many cities and towns are now getting free X-ray examinations. In this way the early

49 X-ray units in vans such as this one may have visited your community. They provide free chest X rays and help keep down tuberculosis.

FEDERAL SECURITY AGENCY

stages of tuberculosis are discovered (Fig. 50). Perhaps one of the X-ray vans shown in Fig. 49 has already visited your school.

Rest in bed, good food, and fresh air arrest the growth of the tuberculosis germ while the body builds up ways to fight it. But the real cure has never been found. Recently, however, streptomycin has been used with some success in certain forms of tuberculosis. So have certain drugs called the isoniazids (eye-so-NY-ah-zidz). With streptomycin, isoniazids, and complete rest, the fight against tuberculosis is gaining ground. You can help by having your chest X-rayed every year and by keeping your body in good condition!

What Progress Has Been Made?

In this chapter you have seen how you have benefited from the work of thousands of scientists. Study the charts shown in Figs. 46, 47, and 48 to see how these discoveries are helping to make your life span longer. In the years since 1930, deaths from pneumonia in young children have gone down about 90%. But Fig. 47 shows that there are more deaths from cancer and heart disease, even though deaths from all causes are

50 This girl is having her chest X-rayed simply, quickly, and safely. Chest X-ray examinations help in the fight against tuberculosis. Your city or county board of health will tell you how you may get an X ray of your chest.

JORDAN, N. Y., STATE HEALTH SERV

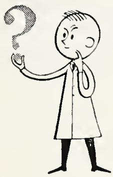
lower. The work is not done; there is plenty for each of you to do in the days to come. What has been done? What do you know to begin with?

Many unseen killers lurk in the air, water, and earth, ready to attack the person who does not keep himself in good health. These killers may be micro-organisms, such as bacteria, viruses, or protozoa, or they may be insects that carry germs. Germs may get into your body through a break in the skin, with the air you breathe, or with your food.

But your body has several lines of defense against disease:

1. Your skin, mucous membranes, and digestive juices.
2. The white blood cells.
3. Antibodies in the blood stream (which may be made by the body or by vaccination and inoculation).
4. Chemical aids like various drugs or antibiotics.

As a result of the experiments and past work of scientists, your life span has been lengthened to an average approaching 70 years (Fig. 48). How long would your average have been if you had been born in 1800? 1850? 1900? Study Fig. 48 carefully. Do you see that because of man's intelligence in controlling disease, you have received a gift of almost a quarter of a century of life ?



LOOKING BACK

Tool Words

Write out your own meaning of each word and then check it with the glossary. Do you have to change your meaning to make it right?

antibiotic drugs (Aureomycin, penicillin, streptomycin)
antibodies
antitoxin
micro-organisms (bacillus [pl., bacilli], bacterium [pl., bacteria], coccus [pl., cocci], mold, spirillum [pl., spirilla], virus)
immunity
inoculation
mucous membrane
toxin
vaccination

Test Yourself

1. When you are sure that you can use the words in the word list correctly, plan a talk on one of these topics:
   a. Micro-organisms
   b. Chemical cures for disease
   c. Scientific studies that need to be made
   d. Recent cures reported in newspaper articles
2. Make up a test for your classmates in which you write the meanings of words from the word list, leaving a blank to be filled in with the word you are defining, for example:
   Rod-shaped bacteria are called . . . .

3. Meanwhile, in order to be sure that you know these words yourself, do this matching test. Copy the words in List A. Before the word write the number of the phrase from List B that best explains its meaning. DO NOT WRITE IN THIS BOOK.

List A	*List B*
micro-organism	1. rod-shaped bacterium
inoculation	2. a substance made in the body that will kill certain disease germs
antibody	3. spiral-shaped bacterium
toxin	4. poison
antitoxin	5. germ
virus	6. a substance put into the blood stream to fight certain disease poisons
bacteria	7. single-celled plants found in three shapes: rods, spirals, spheres
coccus	8. injecting into the body weakened disease germs which will make you immune to the disease
bacillus	9. bacterium shaped like a marble
spirillum	10. a large protein molecule, much smaller than a bacterium, that may cause disease

4. Write a paragraph on the subject "How the Life Span Has Been Increased by Science"; write a second paragraph on the subject "How I Can Help to Increase My Own Life Span." The best papers in the class might be submitted to the school newspaper.

GOING FURTHER

In the Laboratory

1. If your teacher has some prepared stained slides of bacteria, examine them under the high-power lens of a microscope. Then make accurate drawings of each kind for your notebook.

2. Place about 20 cooked peas or beans in a glass of water and allow them to stand for about a week. There will be a foul odor. But there will also be a mass of decay bacteria in the scum which forms.

Heat one end of a needle red-hot. This is to kill any bacteria on it. Then with the needle pick up some of the scum and spread it on a spot near the center of the slide. Again heat the needle to kill any bacteria on it. Allow the slide to dry. Then pass the slide slowly through a low flame four or five times. Stain it with a few drops of methylene blue. (You can get this stain at a biological supply house.) After 1 minute rinse the slide with water several times and let it dry. You have prepared a slide of bacteria. Examine it under the microscope.

3. *Growing Penicillium.* Place an orange or lemon in a moist jar, and set it in a warm room. In a week or so, you will be able to examine the mold that has formed and to see its structure. Can you find its spores?

4. Are there bacteria in soil? Plan an experiment using the microscope to help you answer this question.

Put on Your Thinking Cap

1. How can you tell an anopheles mosquito from a common mosquito?

2. What advice for preserving their health would you give a group of Boy Scouts planning a two-week camping trip?

3. In 1920, in a small town in Ohio, 1,000 people became ill with typhoid fever. Thirty died. If you had been the Health Inspector, where would you have looked for the cause of the disease? What would you have done after you discovered its cause?

Adding to Your Library

1. *Men, Microscopes, and Living Things* by Katherine B. Shippen, Viking, 1955. This is a collection of stories of biologists.

2. You will find three books by Paul de Kruif, published by Harcourt, Brace, very interesting. They contain exciting accounts of the work of pioneer scientists in their battle against disease. These books are *Hunger Fighters*, *Microbe Hunters*, and *Men Against Death.*

3. *Medicine on the March* by Marguerite Clark, Funk, 1949. Here you can read of many experiments and discoveries in the field of scientific medicine.

4. *Microbes at Work* by Millicent E. Selsam, Morrow, 1953. This book includes some easy experiments you can do.

5. *Wonder World of Microbes* by Madeleine Parker Grant, Whittlesey, 1956.

6. *The Story of Microbes* by Albert Schatz, Harper, 1952.

7. *Experiments with a Microscope* by Nelson F. Beeler and Franklyn M. Branley, Crowell, 1957.

The American Cancer Society sponsors a research program on causes and cures of cancer. Write to this society at 521 West 57th Street, New York City, and ask for some of their pamphlets.

A Bit of Research

1. Go to your local Board of Health and ask for figures on pneumonia death rates in your community. Make a graph like the one in Fig. 47 from the information you get there.

2. Place in covered jars slices of different kinds of fruits (apple, orange, banana, lemon, pear). See what kinds of molds grow on the different fruits.

Careers for You

You can see how great is the need for *doctors*, *chemists*, and *bacteriologists* to aid in the many research projects set up to study causes and cures of disease.

Trained nurses are also needed in great numbers. Go to the nearest hospital in your city or town and talk with the supervisor of nurses. Be sure to write for an appointment before you go to the hospital.

CHAPTER 6

Your Community Helps

You are not alone, and never were. Ever since you were a child your community has protected you against disease. Your food was inspected. You had injections against some diseases. Your community stands guard.

You have often looked at pictures of George Washington, but did you know that his face was marred by scars from smallpox?

In the time of Washington an epidemic of smallpox was an accepted evil, for no one was vaccinated in those days. Although Edward Jenner announced his successful use of vaccination in 1798, it was a long time before people would allow themselves to be vaccinated. In Washington's time, being quarantined for smallpox was unheard of. And there was no Health Department to enforce such a law if one had been passed. Health departments are only recent developments.

Let us look at what happened in one of our midwestern cities a few years ago. A case of smallpox had not been known in the city for years, because every school child had been vaccinated or his parents had agreed to keep him at home in case of an epidemic. But one summer a smallpox case was reported. Where the man had been exposed to the disease no one knew, as he had just come to the city. The Health Inspector im-

mediately ordered everyone in the area to be revaccinated. He set up a police guard around several city blocks, allowing no one to go in or out without special permission. He continued this until he was sure that anyone who might have come into contact with the man had been vaccinated.

By this action the Health Department was able to keep smallpox from spreading to others.

Now, in the twentieth century, every community does its best to protect the health of its citizens. We buy Christmas seals, so that the fight against tuberculosis can go on. We buy Easter seals to pay for treatment, equipment, and education for the crippled. We give money to the March of Dimes to help in the fight against certain diseases. We give money to the Heart Fund, and to the Red Cross. The money comes back to help your community. At the same time, your community government makes sure that its citizens have pure water, clean milk, and pure foods. It sees to it that its health laws are obeyed.

As a member of your community, you have a part in guarding your own health and that of your neighbors. You must co-operate with the work of the Health Department and obey its laws.

SAFEGUARDING FOODS

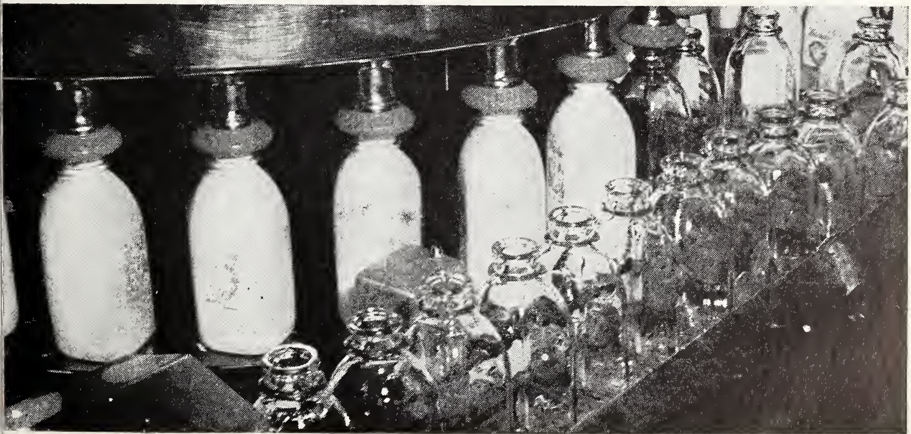
How does your community stand watch over the water, milk, and food that people must have to live? What can you do to help?

Safe Milk

In state and city laboratories every day, experts from the Health Department sample milk from bottles and make a count of the bacteria in it. Generally, they find that the bacterial count (the number of bacteria) is low enough so that the milk is safe to drink. If the count is too high, they investigate. They inspect the bottling plant; then they check the dairy, the cows, and the farmer's milking equipment. They find out if the milk has

1 Your milk comes to you pasteurized, clean and free from disease germs. Once ma-hines like this one go into action, the milk is never touched.

BORDEN'S MILK CO.



been cooled right after milking. Somewhere along the line the milk inspectors will find the reason why the count of bacteria was more than it should be. If the situation is not corrected, they will stop the sale of this dairy's milk.

Most states now have laws which require that all milk sold be pasteurized. This process, called pasteurization, is named for Louis Pasteur, the French scientist who made many important discoveries about bacteria. One way of pasteurizing milk is to heat it to a temperature of about 145° F., keep it there for 20 minutes, and then cool it rapidly. This process kills dangerous germs. The milk is sealed in sterilized containers after it has been pasteurized (Fig. 51).

Tuberculosis, typhoid, diphtheria, and scarlet fever germs, and other kinds of bacteria do not get into milk because laws in many states require:

1. Regular inspection of dairy cows by health officers and the killing of unhealthy cows.
2. Regular inspection of workers who handle milk.
3. Sanitary methods of milking and careful cleaning of milk pails, cans, and milking machines.
4. Cooling of the milk with ice until it is delivered to the bottling plant or creamery.
5. Regular inspection of the bottling plant.

Other Methods of Protecting Food

Buy only inspected meat. Modern meat packers buy and sell only inspected meat. You can see the stamp on the roasts and steaks, showing that the meat has been inspected.

Always cook meat, especially pork, thoroughly. Long cooking kills the trichina, a worm that may be in the meat. This worm causes the disease known as trichinosis (trik-ih-NOH-siss).

Meats may also be preserved by different types of curing. Some meats, such as pork, are placed in smoke from a wood fire. Other meats and fish may be pickled in brine, a salt solution. Bacteria cannot live in salt; the water from their protoplasm diffuses into the strong salt solution. This loss of water kills the bacteria.

Some food today is preserved by *dehydration* (dee-hy-DRAY-shun), that is, by removing the water from the foods. Since bacteria need warmth and moisture to develop, removing either of them helps preserve the food. Refrigeration removes the warmth; dehydration removes the water.

In canning, some foods are preserved by heating to a temperature which kills bacteria. Then the inside of the can or glass jar is kept free of bacteria by sealing it while the food is hot. Once a can or jar of food is opened, what is not eaten should be kept in the refrigerator.

Food, especially meat, kept in a warm place begins to decay. That is, certain bacteria begin to grow in it and may make poisons known as *ptomaines* (toh-MAYNZ). Ptomaine poisoning often causes serious illness and even death. It is not sensible to eat any food that has the slightest odor or taste that might show that the food has been spoiled.

SAFEGUARDING WATER

When you are thirsty, you usually take a drink of water. You get it from

a faucet or a pump or a drinking fountain. You know that there are bacteria everywhere. You know that many of these bacteria live in soil from which your drinking water comes. Yet you have faith that your drinking water is safe. Is it because your community or your family makes sure that there is safe drinking water for all people who live there?

Let us follow a drink of water from its source in the clouds to its destination, your drinking glass. You will see why water comes to you fairly free from germs.

Getting Water from a Spring

Perhaps part of your drink of water fell as rain on a hillside near a farmer's house. It sank into the ground and became a part of the water in the soil. This water sank farther and farther down until at a certain depth all the soil was *saturated* with water. This means that the soil was holding all the water it could take in. Some distance below this point, the water was stopped by a solid layer of rock, or a very hard layer of soil, which sloped toward the farmer's house. The water then flowed down this underground slope to a deep, stone-lined basin which the farmer had built. Here the water was trapped. It filled the bottom of the deep basin and either flowed out or was pumped out.

The soil itself acts like a filter. As the water seeps through, the soil removes particles from it.

Even though water from an open spring looks clear, you must always be careful. It is wise not to drink spring water unless it has been inspected and declared safe for drinking.

A Well on a New York Farm

As you now know, when water sinks into soil it reaches a point where the soil particles hold as much water between them as is possible. The top of this saturated soil layer is called the *water table*. To have enough water on a farm, it is very important that the water table be high.

Let us take a look at the water table on this New York farm. The water table here is usually about 10 feet below the surface after a heavy rain, and about 16 feet from the surface in dry weather. The owner of the farm has dug a well about 22 feet deep, with walls of stone to keep the soil from falling in. Rain water seeps through the ground and enters the well at its bottom. Of course, the water in the well usually stands at about the height of the water table (Fig. 54).

In severe droughts the water table goes down, and the farmer's well goes dry. Even if his well were dug far below the level of the water table, he would be in trouble in a dry spell. He still would have to depend upon new rain water seeping through the soil. Unless there was much rainfall, he would need a deeper well. Some farmers have a well driller drive a large pipe deep into the ground 100 feet or more into water-holding rock. Water from such wells is usually pure and safe to drink.

In many parts of our country much more water is being used than is being given back to the land by rain and snow. In such places the water table is dangerously low. In times of drought, cattle die for lack of pasture and water for drinking. Crops fail. Factories shut down. Water should be carefully used. In Unit 6 the

problem of saving water will be studied carefully.

Artesian Wells

A well in which the water may rise above the water table is called an *artesian* (ar-TEE-zhun) *well.* The water may flow out or even spurt out at the ground level.

To drill an artesian well, our New York farmer rented a well-drilling machine. With it he drilled down through a layer of solid rock into a layer of soft sandstone 200 feet below the surface of his farm (Fig. 53). The water which entered this artesian well may have come from many miles away, traveling along this layer of soft rock far below the surface of the ground. The water could not escape, for it was held in this soft, porous rock by the pressure of solid rock layers above and below it. When the well-drilling machine pierced the layer of solid rock, the water was forced upward and gushed from the drill hole. The farmer now had an artesian well.

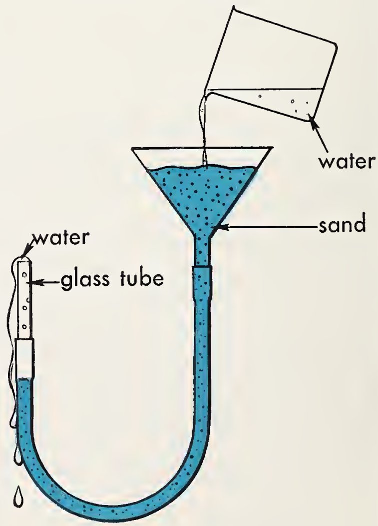
Water Seeks Its Own Level

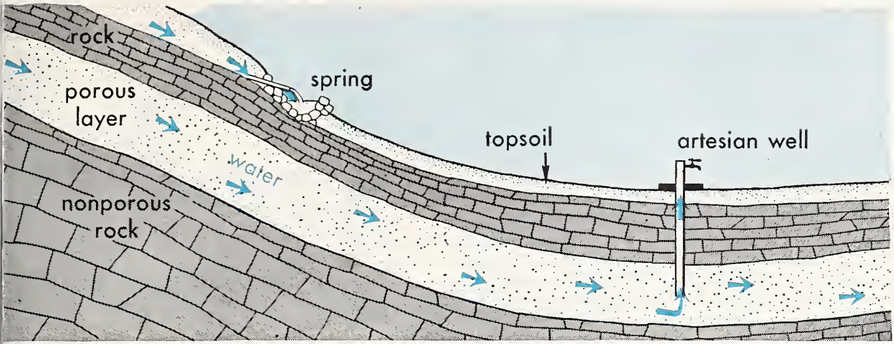
Why does artesian well water come to the surface? Make a rough model of an artesian well to see the way it works. Take a large-sized funnel like the one in Fig. 52 and fill it with sand. Attach it to 2 or 3 feet of rubber hose, which has also been filled with sand. Fit a glass tube into the other end of the hose. The funnel with sand stands for the porous rock layer surrounded by the nonporous rock. The glass tube stands for the pipe drilled into the rock.

Hold the glass tube higher than the funnel, and fill the funnel with water. Now lower the glass tube slowly till you see water in it. Compare the water level in the funnel with that in the tube. They are the same, aren't they? If you hold the tube over the sink and lower it below the water level in the funnel, the water will flow from the tube as it sinks in the funnel. Water, you see, seeks its own level.

In our New York farmer's artesian well, the porous rock (Fig. 53) collected the water at a level higher than the opening which the farmer had drilled. The height of the source of the water is part of the reason why the water rises so high in an artesian well. The other reason is the hard layers of rock which hold the water much as a pipe does. The hard rock allows the water to escape only at the place where the artesian well is

52 How an artesian well works. The sand in the funnel stands for porous rock, the rubber hose for the hard rock layers above and below the porous rock, the glass tube for the pipe which the well driller sinks. (See Fig. 53.)





3 How water gets to an artesian well. The rock layers trap the water in the porous layer. ere it remains under pressure until tapped by the drilled well.

drilled. Why is artesian well water pure and safe to drink?

Pure Water on the Farm

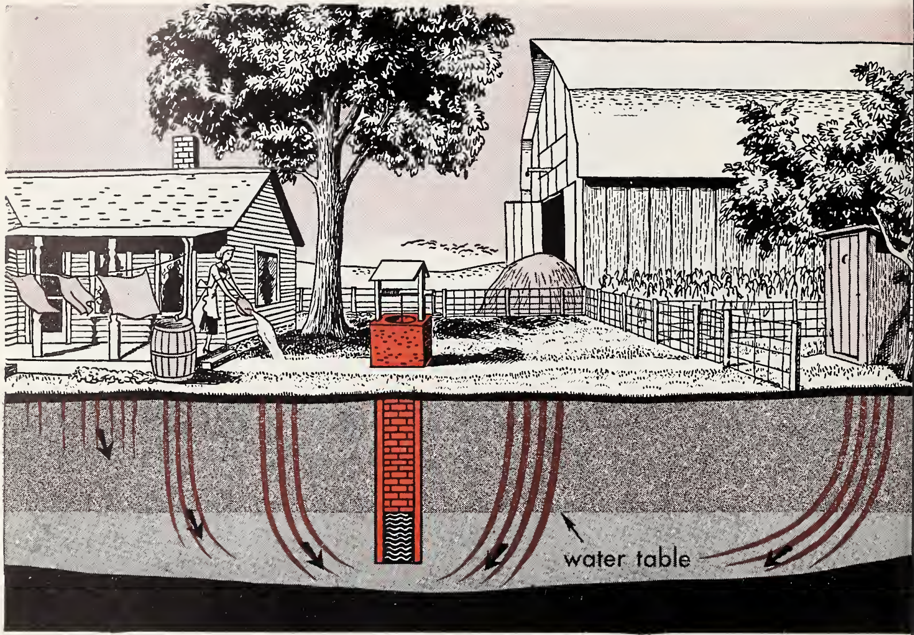
Whether our water comes from springs, wells, or faucets, our main concern is, is it safe for drinking? If wells are carefully built, so that no surface water or drainage from germ-laden water can get in, well water is safe to drink. Remember that the water as it seeps through soil and rock is freed from most bacteria.

There can be danger. Suppose an outhouse, barn, or manure pile is placed at a higher level than the spring or well (not an artesian or driven well). During rains, some of the sewage will seep into the water and may get into the well.

Getting Rid of Sewage

Since typhoid germs can breed in water into which sewage is dumped, getting rid of sewage is one of the most important problems handled by your community. In the city, sewage is usually put through a chemical process that makes it harmless. Some cities, like Detroit, for example, have been experimenting with making garbage into fertilizer for farm lands near the city. Because much garbage is made up of plant wastes from the kitchen, it is a good practice to return it to the soil. Other cities have large garbage-disposal plants where garbage is burned. In some of the newer homes, a garbage-disposal unit is connected with the kitchen sink. None of the garbage has a chance to get into the drinking water.

On the farm, getting rid of sewage and garbage is a different problem. Since the farmer must guard the health of his family, he must make careful plans for the disposal of sewage and garbage. Part of the kitchen garbage can be fed to some of his animals; the rest can be buried in the ground. Sewage needs to be kept far away from wells and the milkhouse. It is good health practice to place outhouses and manure piles to one side of and below the source of drinking water, and at least 100 feet away from it. Is the well in Fig. 54 in a safe place? Where there are indoor toilets on the farm, the septic tank, sunk in



54 The water in the well is not safe to drink. Why? The clue is in the black arrows tha show how moisture gets to the water table. Where should a well be placed for safety?

the ground, should be placed at least 100 feet away from the source of water.

Safe Water for the Millions

Getting water into the faucets of cities like New York or Cleveland or San Francisco is a great engineering accomplishment. Your glass of city water usually comes a long way to your faucets.

New York City water, for instance, begins its travels in the Catskill Mountains 80 miles away. It flows into one of the large artificial lakes built by damming several rivers, which get their water from many creeks. These creeks collect the rain water from a large area, called the *watershed*. The water finally runs into the Ashokan (a-SHOW-kan) Reservoir. The water in this reservoir alone could cover all of Manhattan to a depth of 25 to 30 feet. Other reservoirs have also been built to supply enough water for the great city of New York.

From the Ashokan Reservoir, the water flows through large pipes for 120 miles, up hill and down, and under the Hudson River. This system of pipes is called an *aqueduct* (AK-wuh-dukt). It is 40 feet wide in certain places. At one point, the aqueduct is 1,200 feet below the surface of the ground.

The source of the water for New York City is so high that water will flow as high as the twentieth story of most buildings. However, taller buildings need to have their water

pumped to the faucets in the upper stories.

San Francisco has water supply problems similar to those of New York. At the present time, San Francisco depends on a fast-flowing river high in the mountains. This river was dammed up to form a system of three reservoirs which supply San Francisco with water (Fig. 55).

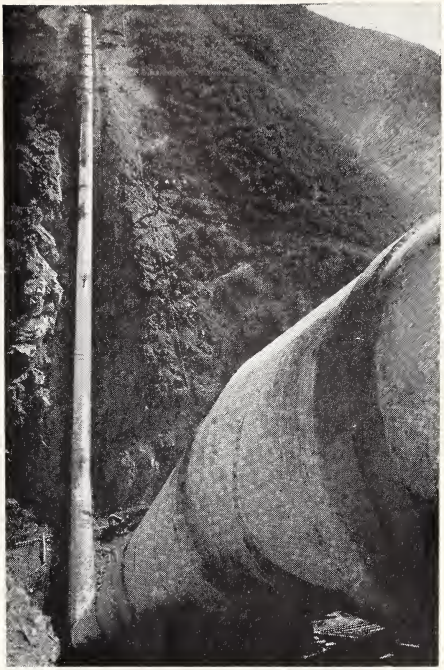
Cities, such as Cleveland, on the level plains and around the Great Lakes have a different problem. Because the source of their supply is either a slow-moving river or lakes on about the same level as the city, they have to use great pumps to bring their supply of water to the city reservoirs. They also have the problem of purifying the water before it goes to the customer.

How do cities treat their water supply to purify it and thus give you a safe drink of water?

Water Fit to Drink

Suppose we were to dump some soil into a glass of water. You know that soil contains bacteria. How would you make that water fit to drink? You could filter it through a filter paper to get rid of soil particles. Then you would have to boil it thoroughly to kill the germs. But then it would have a flat taste because boiling drives the air out of water. To restore the taste you could pour the water back and forth, from one glass to another. By this method you would *aerate* (AY-er-ayt) the water. Air will enter the water as you pour it back and forth.

Purifying one glass of water takes time, but suppose you had to purify millions of gallons of water daily. That job is one your community does for you.



FREDERICK LEWIS

55 In large pipes such as this, called aqueducts, water reaches the city of San Francisco. How does water reach your city, town, or village?

Getting Rid of Particles in Water

As water stands in reservoirs, most of the heavier particles settle to the bottom. To hasten the removal of impurities, many cities send their water through settling basins or *filtration* beds. In a filtration plant there are a large number of concrete filtration beds, each of which has layers of sand and gravel. Soil and other particles, as well as germs, are caught in these beds. At the bottom of each bed there is a large pipe which leads to other large water pipes or mains. At last the water reaches your home.

To make a model of a filtering bed, use a funnel with sand and gravel, like the one in Fig. 52. Pour muddy water through it and see how clean the water is after it has come through the sand.

In some large settling basins, the particles in water may be made to settle faster by the use of chemicals. Alum is added to the water to make bacteria as well as particles settle quickly.

Make a model settling basin, to see how one works. Take some alum and add it to limewater. You will notice that a thick, white substance called aluminum hydroxide is produced. This substance settles quickly to the bottom.

Killing the Bacteria

Aeration comes next. The water is sent up in sprays into the sunlight and air, which help in killing bacteria. Aeration, by adding air to water, restores the taste and helps remove odors. However, aeration is not enough to kill all the bacteria.

While the water is still in the mains and before it reaches the faucet, chlorine gas is added. Chlorine gas is poisonous, but it is added in such small quantities that it kills the bacteria without harming people. And now the water is fit to drink.

CONTROLLING MODERN PLAGUES

In 1665, a dread disease carried by rats, the Black Death, wiped out almost one-third of the population of London. Such a thing could not happen in a modern city. Why not?

Keeping Plagues from Starting

In your community, the Health Department keeps up a continual war on rats. Why kill rats? Rats carry the flea which in turn carries the bacterium of bubonic plague. This disease was the Black Death that killed so many Londoners in 1665.

You have read how smallpox has been conquered by health officers. The Health Department tries to stop disease before it can spread. School children are vaccinated for smallpox. In school they are also given the Schick test and treatment to prevent diphtheria. Health officers work with the Red Cross in giving X-rays to catch the first signs of tuberculosis. Teachers are also trained to notice the first signs of disease.

Imprisoned at Home

In your town or city, you will find your health officers carrying on a campaign to prevent the spread of diseases like measles and scarlet fever. In large cities and towns where people live close together, it is very easy for germs to travel from one person to another. It is easy for people themselves to spread disease. Hundreds of persons used to die of smallpox, diphtheria, and other *communicable* (kuh-MYOO-nih-kuh-b'l), or catching, diseases. Even today, measles, mumps, chicken pox, and scarlet fever are spread because one person passes the germs of the disease to another person. Nowadays, when someone shows symptoms of a communicable disease, he is kept away from other persons. On the house door the health officer tacks a *quarantine* (KWAHR-en-teen) sign. To quarantine means to keep persons

from coming in or going out. With some diseases, adults in the family are allowed to go in and out as usual. With certain other diseases, where there is danger of germs being carried in clothing, no one is allowed to leave the house until all danger is past.

You can help prevent the spread of disease by obeying the quarantine sign. You can stay away from other persons if you think you may be "coming down with something." And you should see a doctor.

Quarantine is useful to you. The next time you see a quarantine sign on a door, you will know that your community is safeguarding your health.

LOOKING BACK

Tool Words

What does each of the following words have to do with community health? Before you answer this question, do the matching test below.

aeration	filtration	quarantine
artesian well	pasteurization	trichinosis
chlorine gas	ptomaines	water table
communicable		

Test Yourself

a. Select the correct word from the word list above to match each meaning below. Place it before the meaning and write the complete sentence in your notebook. DO NOT WRITE IN THIS BOOK.

1. poisonous gas used to purify water
2. a disease caused by eating underdone pork having a certain kind of worm in it
3. spraying water into the air to help purify it and restore its taste
4. poisons in decaying food
5. the height at which water is standing below the surface of the ground
6. a gushing or flowing well
7. keeping a person with a communicable disease away from other persons
8. a disease that can be passed from person to person
9. killing bacteria in milk by heating it to 145° F.
10. getting impurities out of water by passing it through layers of sand and gravel

b. Complete the following sentences by filling the blanks. DO NOT WRITE IN THIS BOOK.

1. You can purify a glass of water and make it tasty for drinking by (*a*) . . . , (*b*) . . . , and (*c*) . . . .

2. Water flows from an artesian well without the aid of a pump because (*a*) . . . , and (*b*) . . . .

3. To keep milk safe for use, most states have laws requiring (*a*) . . . , (*b*) . . . , (*c*) . . . , (*d*) . . . , (*e*) . . . , and (*f*) . . . .

GOING FURTHER

In the Laboratory or Field

1. Visit one or more of the following places with your teacher and class:

a. A filtration plant where water is purified.

b. A milk-bottling station or a creamery.

c. A dairy farm to see how the milk is kept free from bacteria.

2. Find out how water is brought to your faucets. Where does the water come from? Where and how is it purified?

Put on Your Thinking Cap

As you grow older, you will be faced with the questions: Shall I smoke? Shall I drink?

The decisions that you make on these two questions will have some effect on your health. What are the scientific facts about the effects of smoking and of drinking alcoholic beverages?

1. *Effects of smoking.* Does smoking affect a person's health? Dr. Raymond Pearl of Johns Hopkins University gathered this information which you should know.

Approximately 66,000 nonsmokers out of every 100,000 aged 30 may expect to reach 60 years of age.

Approximately 62,000 moderate smokers (two or three cigarettes a day) out of every 100,000 aged 30 may expect to reach 60 years of age.

Approximately 46,000 heavy smokers out of every 100,000 aged 30 may expect to reach 60 years of age.

You may want to read more about tobacco and its serious effect on the body. Frequently newspapers and magazines have articles on lung cancer and its relationship to smoking. Also, send for the first pamphlet listed under "Adding to Your Library."

2. *Effects of alcohol.* As you get older you may also want to know the answer to this question: What effect does alcohol have upon a healthy body?

You should know the facts. Here are facts gathered by a committee of scientists and published in the book on alcoholism listed under "Adding to Your Library."

About one-fifth of all deaths in traffic accidents are caused by drunken drivers or pedestrians.

With 0.003% alcohol in the blood (only 3 drops to 100,000 drops of blood), unconsciousness results. Six drops per 100,000 drops of blood may cause death.

Constant and regular drinking of alcoholic beverages may result in a disease called alcoholism. This disease is dangerous to life and to mental health.

Adding to Your Library

1. *How Alcohol Affects the Body* by Mark Keller, Yale Center of Alcohol Studies, New Haven, Conn., 1955.

2. *High School Hurdles*, School and College Service, Columbus, O., 1956.

3. *Dental Projects for High School Science Students*, American Dental Association, New York, 1959. If you have a real interest in teeth, here are some activities to spark your imagination and get you started on solving some fundamental science problems.

4. *Your Health and Safety*, 4th edition, by Jessie W. Clemensen and others, Harcourt, Brace, 1957. Unit 7, "Your Part in Preventing Disease," will add to your information on the topics covered in this unit.

A Bit of Research

1. Under the microscope examine some milk just taken from the refrigerator. What do you see? Let some of this milk stand at room temperature. Then examine some of the milk under the microscope. What do you find?

2. Gather all the articles you can on the effect of smoking on cancer. What are your conclusions?

Careers for You

Engineers are needed to construct community filtration plants and other municipal projects.

Milk inspectors, *veterinarians*, and *dairymen* will always be needed in work connected with our milk supply.

City health nurses, *school nurses*, and *health inspectors* can help in the community battle to keep its citizens healthy.

a LIFETIME hobby—

SAVING YOUR OWN LIFE AND LIMB

Do you know this fact? Before you have finished reading this page, a man, woman, or child will die in the United States. Not from disease or warfare, but from CARELESSNESS on somebody's part. In the few seconds in which you were reading these three sentences, some man, woman, or child was injured by an accident. Again, CARELESSNESS.

In April, 1945, the United States Army, Navy, and Marine forces invaded Okinawa in the Pacific. The Japanese fought stubbornly; 82 days of fierce fighting were needed to make them give up. The price we paid for that victory was 43,376 casualties, of which about 5,000 were deaths.

In the same 82 days back home in a United States untouched by bomb or bullet, 22,000 people died. From disease? No, these people died in accidents. During this period (82 days), 2,300,000 people suffered accidental injuries. Yet many of these accidents could have been prevented.

Suppose you saw this headline in a newspaper:

105,000 KILLED

You might suppose that a new atomic bomb had exploded. You would be wrong. This is the number of Americans killed in 1952 by accidents. Each year in the period from 1935 to 1954, about 100,000 men, women, and children were killed in accidents in the street, at work, or at home. During the same period about 10 million were injured each year. In the last few years, the accident rate has been lowered somewhat. In

1957, for instance, approximately 88,000 died in accidents, while just over 10,000,000 were injured.

Records kept by the National Safety Council, an organization for promoting safety in the United States, show that most accidents happen at home. This is the place where everyone can begin to prevent accidents.

Your Part in Preventing Accidents at Home

You can make it a regular job, an important job, to check your home for six main danger spots. In this way you will help save yourself and members of your family from serious hurt.

Check the danger points listed below *today*. For each "yes," give yourself plus 10; for each "no," minus 10. Keep a careful record of your score. Correct the "no's" as soon as you can.

1. *The hallways*. Falls are the cause of most injuries in the home. Are there rubber mats under loose carpets to prevent slipping? Are toys, especially marbles or toys with wheels, put away where no one will slip and fall on them? Are hallways and stairways well lighted?

2. *The bedrooms*. Is there a light near each bed which may be put on if light is needed?

3. *The bathroom*. Wet, slippery bathtubs cause many home accidents. Has the bathtub a small handrail? If not, has it a small rubber mat on which one may step?

Examine the medicine cabinet. Does every bottle have the right label? Are the bottles out of the reach of young children? Is there a place to get rid of used razor blades so that no one can be cut?

4. *The electric wiring*. Are electric wires safely covered? Many babies and small children are killed each year by frayed lamp cords and poor wiring. *Do not touch frayed wires unless the plug is out of the socket.*

5. *Storage space*. Is everything stored so that heavy objects will not fall on your head? Are stored things easy to get at? Are the heavier things on the floor? Are the lighter ones on the upper shelves?

6. *The house at night*. Before you go to bed, do you check these danger spots?

Is the gas stove turned off?

Are outside doors closed and locked?

Are open windows arranged so that you are protected from rain or snow?

If you were to get out of bed in the dark, would you trip over something near the bed? If so, remove it.

A score less than perfect means that your home is dangerous to the health and safety of you and your family. Remember, every year about 20,000 people under 20 years of age die from accidents. You will not be one of them.

Your Part in Preventing Accidents in the Street and Playground

Give yourself 10 points for every "yes," and minus 10 for every "no." You are living dangerously and thoughtlessly if you get a score lower than 90.

1. Do you cross the street at safe points and only with the traffic light?

2. Do you play in a playground rather than in a street?

3. Do you wear sneakers rather than leather-soled shoes when you play on cement, grass, or polished wood?

4. Do you wear boots or rubbers when you walk on ice or snow?

5. If you need to wear glasses, do you wear them instead of leaving them at home or in your pocket? (If you do not wear them, you may not see danger in time to react quickly.)

6. If you wear glasses, are they protected by a guard when you play on the school playground?

7. Do you keep from climbing over barbed wire or iron picket fences?

8. Do you keep on the right side of the road when cycling? When walking, do you keep to the left side of the road facing traffic?

9. Do you report injuries to your parents or teachers?

Your Part in Preventing Accidents at School

In which of these columns are you — the wrong or the right?

Wrong	*Right*
Do you	Do you
1. Run in the halls and leap up and down stairs?	1. Consider others while walking in halls or up and down stairs?
2. Fail to report a broken chair?	2. Report any broken furniture, to prevent injury to yourself and others?
3. Make yourself a nuisance during fire drills?	3. Co-operate to save lives, by getting out of the building as rapidly as possible without talking or jostling?
4. Play games on wood or cement floors without sneakers?	4. Co-operate by wearing proper shoes and clothing in the gymnasium?
5. Wear glasses without a guard while playing basketball or football?	5. Wear a guard over glasses in ball games?

Were you always on the right column? For your safety's sake, you must be!

This is only the first of a number of interesting hobbies you will find throughout this book. For instance, there will be hobbies in astronomy, chemistry, photography, and building model airplanes. But your first hobby should be PREVENTING ACCIDENTS, or, as we have put it, "Saving Your Own Life and Limb."

You have heard the saying, "The life you save may be your own." As you save your own life — as you prevent accidents to yourself — you save the lives of others.

UNIT 3

Exploring the Earth and Space

The years 1957 and 1958 were great years in science. Scientists of 66 nations pooled their resources and their brains to try to learn as much as possible about the earth and space during an eighteen-month period known as an International Geophysical Year — IGY for short.

One of the goals of one team of scientists was to map the frozen wastes of Antarctica, a vast continent around the South Pole. But this was only one goal; they made new discoveries about the earth's magnetic field, investigated weather conditions, learned more about man's ability to survive in an unfriendly climate, and performed many other studies.

Other teams of scientists over the world explored space, for this became the age of the first satellites. Their great deeds are only the forerunners of greater conquests yet to come. Perhaps you will be one of the early space explorers. By the end of this unit you should be able to read with understanding of man's future attempts to conquer space. You will take pride, too, in the opening of a new frontier.

Your Science Inventory

How much do you already know about exploring the earth and space? Copy the following questions in your notebook and write your best answer for each one. After you have read this unit, check your answers to see how many you had correct.

1. The red planet is (a) Jupiter, (b) Mars, (c) Mercury, (d) Saturn.
2. A danger you would *not* need to worry about if you were a moon explorer is (a) being drowned, (b) freezing to death, (c) high temperatures, (d) lack of oxygen.
3. The sun is a mass of (a) gas, (b) liquid, (c) solids, (d) liquids and solids.
4. What really moves when you see a star twinkle is the (a) air, (b) earth, (c) outer space, (d) star.
5. When you see a shooting star, you are really looking at a (a) comet, (b) meteor, (c) planet, (d) star.
6. The planet Mars has (a) 1 moon, (b) 2 moons, (c) 4 moons, (d) no moon.
7. Our earth is a planet in (a) the Big Dipper, (b) Leo, (c) the Little Bear, (d) the Milky Way.
8. When it is noon in New York, the time in San Francisco is (a) 9 A.M., (b) 12 noon, (c) 3 P.M., (d) 9 P.M.

9 To use your watch as a compass you must point the (a) hour hand toward the sun, (b) hour hand away from the sun, (c) minute hand toward the sun, (d) hour hand straight down.

10 The distance from the surface to the center of the earth is about (a) 1,000 miles, (b) 2,000 miles, (c) 4,000 miles, (d) 8,000 miles.

11 As a satellite moves away from the earth, its weight (a) decreases, (b) increases, (c) remains the same, (d) cannot be predicted.

12 Spring tides occur (a) at full moon, (b) at new moon, (c) once a month, (d) twice a month.

13 Suppose that you had a space ship in which you could move from one heavenly body to another. You would weigh most on (a) Jupiter, (b) Mercury, (c) the earth, (d) the moon.

14 If you were to travel through outer space, you would not need (a) a supply of oxygen, (b) pressurized clothing, (c) to be concerned about radiation dangers, (d) the pull of gravity.

15 Scientists say that a volcano is somewhat like (a) an avalanche, (b) a pressure cooker, (c) a safety valve, (d) a tornado.

CHAPTER 7

Our Sun and Its Planets

Have you seen the sun just showing through clouds? Here it is hidden by the moon. This star — your star — is the one from which comes the energy you use in your daily living.

THE CAVE MEN drew pictures of star groups on the walls of their crude homes. Perhaps they, like most men in historical times, wondered whether there was life elsewhere in the universe. No one knows. But we all may wonder whether life might exist on one of the earth's neighbors or on an earth-like body near another star.

Until we visit other planets we cannot know for certain whether life ever existed there or not. But astronomers and biologists working together can help us in our guessing. They can tell us about the temperature, water, and atmosphere of other planets. From this we can decide whether life there is possible or not.

Life has many different forms. Very small things have been found living in the boiling waters of hot springs. Scientists who study the ocean have found strange creatures living in the cold, dark waters thousands of feet down in the sea. If life can be found under these conditions, is it not possible to think of life in some form on another planet? This form of life need not be the same as life on our planet.

You can answer this question for yourself later on. First you will need to know what conditions are needed for the life of the plants and animals we know. Then you will need to know something about our other planets and what conditions are to be found on them.

Once Upon a Time

People long ago spent a good deal of time wondering about what they saw in the heavens. A teacher named Aristarchus (air-iss-TAR-kus) of Samos (SAY-mus), an island belonging to Greece, said that the earth moves around the sun. This teacher lived between 310 and 250 B.C.

Another teacher named Ptolemy (TOL-eh-mee), 100–171 A.D., did not agree with Aristarchus. He said the earth is the center of the universe, around which the moon, sun, and stars move. Because people like to think of their home as the center of things, Ptolemy's idea was taught for over a thousand years.

On May 24, 1543, Nicholas Copernicus (kuh-PER-nih-kus), a Polish astronomer and teacher, wrote a book setting forth some new ideas about the earth and the motions of the other objects in space. His book began to change men's thinking about the universe. Copernicus believed with Aristarchus that the sun, not the earth, is the center of a system of planets. Now we know without doubt that our home, the earth, is only a small speck in space — but an important speck to all of us.

In this chapter we want to take you on a trip through space to show you something about the earth's place in the sun's family, which we call the *solar* (SOH-ler) *system.*

THE SUN AND ITS FAMILY

Let us suppose we are space travelers looking at the solar system from somewhere out in space. Also let us suppose we have with us a powerful telescope. What will we see?

Planets Around a Star

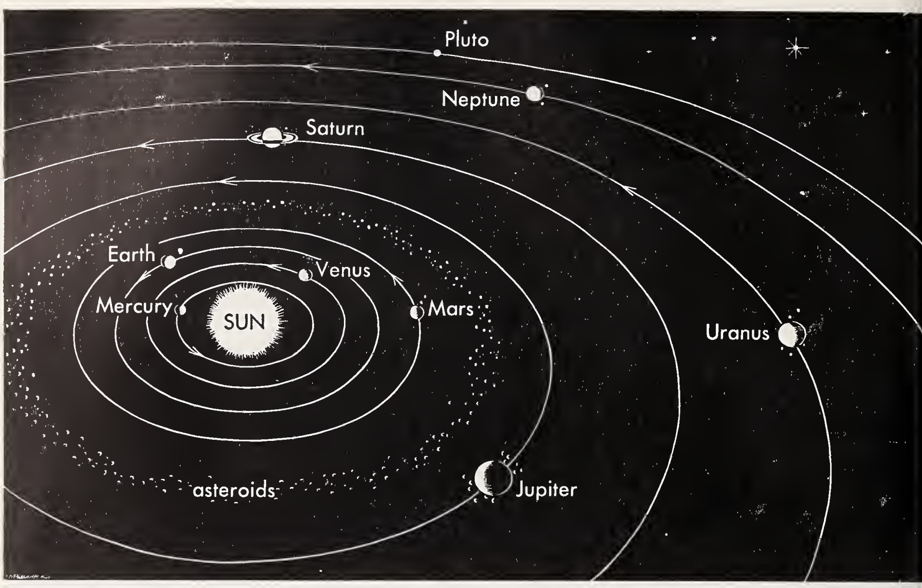
First we will look for and find nine planets of different sizes. Four are smaller, and four are larger, than the earth. The planets all travel around the sun in paths called *orbits.* The orbits which the planets follow are nearly round (Fig. 56).

When a planet travels around the sun, it is said to be revolving around it. When a planet has made a complete trip in its orbit around the sun, it is said to have made one *revolution* (Fig. 56). The time it takes the earth to make one revolution around the sun ($365\frac{1}{4}$ days) is called a year.

Only 36 million miles from the sun is a planet that makes a complete trip around the sun in only 88 of our days. Its name is Mercury, and it is only about 3,000 miles in diameter. The *diameter* of a round object, like a ball or a planet, is the distance from one side to the other measured through the center.

There are eight other planets that go around the sun just as Mercury does. Study the chart on p. 137 and compare the planets which are neighbors of your planet, Earth.

Between Mars, the reddish-looking planet, and Jupiter is a swarm of tiny planets, called *asteroids* (AS-ter-oydz) or *planetoids* (PLAN-et-oydz). None of these is known to be larger than the one called Ceres (SEER-eez), 488



56 The solar system is the sun's family of nine planets, 31 moons, and hundreds of tiny planets called asteroids. Jupiter is larger than all the other planets put together. Not shown are the hundreds of comets which also belong in the sun's family. *Exhibit:* Use the front of your room, above the blackboard, as a bulletin board. On it, plan a display to show the relationship between the sun and its planets.

miles in diameter. Each of these planetoids has its own orbit around the sun. More than 1,500 have been discovered, but their number probably is more than 50,000.

Beyond Jupiter is Saturn, the outermost planet visible to the unaided eye. It has three rings of small moons called moonlets, but these cannot be seen without the aid of a telescope (Fig. 58).

As you will see in Fig. 57, six of the nine planets have moons. In all there are thirty-one moons. Earth has one moon; Neptune and Mars have two each; Jupiter has twelve; Saturn, nine; and Uranus, five. No moons are known for Mercury, Venus, or Pluto.

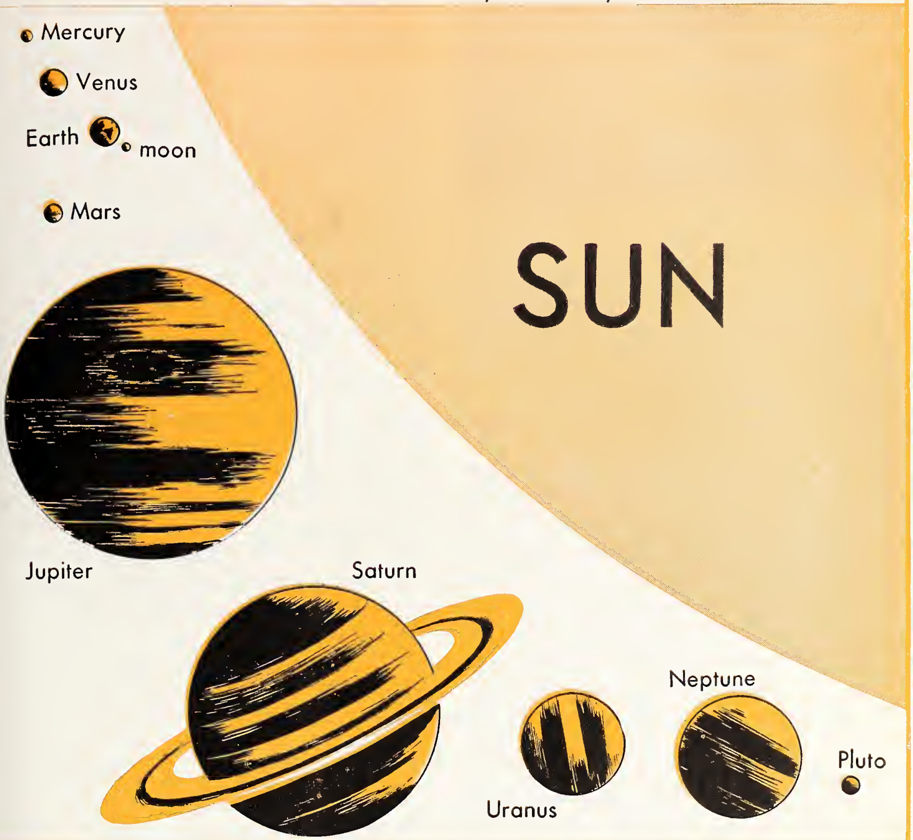
These nine planets with their moons and the planetoids are the chief members of the sun's system, the solar system. Of course there are some other sky objects in our solar system you may know of. You will learn more about them in this chapter.

Our Daytime Star

You may have guessed by now that just as the earth is not the only planet in the sky, so our sun is not the only sun in space. Actually, each star is a sun, and our sun is a medium-

57 Planets are not the only members of the sun's family. Not shown here are the moons, comets, and planetoids which are also part of the solar system. Tiny Mercury is the planet nearest the sun; Pluto, the farthest away.

RELATIVE SIZES OF THE SUN, MOON, AND PLANETS



DISTANCES from Earth in Miles*

The moon	240,000
Venus	26,000,000
Mars	48,000,000
Mercury	57,000,000
The sun	93,000,000
Jupiter	390,000,000
Saturn	793,000,000
Uranus	1,690,000,000
Neptune	2,700,000,000
Pluto	3,573,000,000

*If you wanted to travel to these places the distances would be much greater because a space rocket cannot travel in a straight line.

SIX PLANETS HAVE MOONS†

The earth has	1
Mars	2
Neptune	2
Uranus	5
Saturn	9
Jupiter	12
Total	31

†Our moon is 2,160 miles in diameter. The smallest, Mars's moon Demos (DEE-moss), is 5 miles in diameter. The largest, Jupiter's moon Ganymede (GAN-ee-meed) is 3,200 miles in diameter.


YERKES OBSERVATORY

58 Saturn, second largest planet, when seen through a telescope, is easy to recognize because of its rings. These are made up of tiny moonlets. *Project:* Collect pictures of the different planets (as they appear in newspapers and magazines). Title your exhibit "The Earth's Neighbors."

sized star. Even so, our sun is more than a hundred times as large in diameter as the earth. The sun's diameter is about 864,000 miles. If you were to fit planets the size of the earth inside the sun, much as you might pack the inside of a large balloon with marbles, it would take more than a million earths to pack the inside of the sun. Remember, however, that the sun is not hollow inside, nor is it like a balloon.

Until the 1600's, people thought of the sun as a spotless, fiery ball. But in 1610, with a telescope he had made, Galileo (gal-ih-LAY-oh), the famous Italian scientist, saw spots on the sun's surface. By watching the motion of such spots, astronomers learned that the sun rotates or spins. They also found that the sun is not solid like the earth, but gaseous, which means "made of gas."

Although the sun is a globe of glowing gas, it weighs 1.4 times as much as an equal volume of water. No human being could come within 50 million miles of it without burning up. The temperature on the outside is about 10,000° F. Its temperature inside, although not really known, is probably about 68,000,000° F. Only a tiny part of the heat sent out by the sun reaches the planets. The earth gets about one-billionth part of the total heat the sun sends out.

Who's Who in the Sky

As you look around the night sky, can you see a horse with wings, a couple of bears with long tails, a lady in a chair, and another lady in chains? Can you see a couple of fishes, each with a ribbon tied to its tail? Can you see a crow standing on the back of a serpent? Can you see the long hair of a queen? Can you find a lion, a crab, a dog, a swan, and a ram? Is all this a joke? Not at all. These are what ancient people thought they saw in some star groups, or *constellations*, as they are called. And so these constellations have been named for ancient heroes or for animals. We still keep these names today (Fig. 59).

We must admit that it is very hard to see these figures in the sky. It is as though a stranger to our country were to try to see a map of Washington, D.C., in a picture of George Washington. To a modern astronomer, a constellation is not merely a pattern made by a group of stars but a part of the sky. Just as a map maker first divides the surface of the earth into continents, so the astronomer divides the sky into constellations.

You can find only a few of the 88 constellations at *any one time* because less than half of the earth's entire sky can be seen from where you are standing. But remember, the earth is turning, so that a few months later

you will see other stars overhead. If you look at the stars every night (weather permitting) at the same time for a year, you will be able to see all the stars that can be seen with the naked eye. To see the rest of the stars, you would have to go to the Southern Hemisphere and keep watching the stars at night for another year. Even then you would see only a very small number of the stars, for many are too dim and far away to be seen even with the earth's most powerful telescopes.

If you are interested in astronomy and would like to start some long-range projects on your own or in a group, look over pp. 625–660 and make plans.

Whether you watch the stars at night or not, you can learn a great deal about them if you live in or near one of twenty cities: Baltimore; Boston; Buffalo; Chapel Hill, N.C.; Charlestown, W.Va.; Cherokee, Iowa; Chicago; Kansas City; Los Angeles; Nashville, Tenn.; Newark, N.J.; New York City; Philadelphia; Pittsburgh; Portland, Ore.; Provi-

A Model of the Solar System

To get some idea of the size and organization of the solar system let us make a model of it. For convenience we shall reduce the sun to a tennis ball almost three inches in diameter. Since the sun is almost 900,000 miles in diameter, the scale of the model will be three inches for one million miles, or four million miles per foot, or 330,000 miles per inch. The diameters and mean solar distances of the planets are listed below; in your notebook reduce them to the scale model — diameters in inches and distances in feet. DO NOT MARK THIS BOOK

Object	*Solar Distance*		*Diameter*		*Typical Object*
	Actual (millions of miles)	*Model (feet)*	*Actual (miles)*	*Model (inches)*	
Sun			866,000	2.6	tennis ball
Mercury	36.		3,100		
Venus	67.		7,700		
Earth	93.		8,000		
Mars	140.		4,200		
Jupiter	490.		89,000		
Saturn	890.		74,000		
Uranus	1,800.		32,000		
Neptune	2,800.		31,000		
Pluto	3,700.		6,000?		

The moon is about 2,000 miles in diameter and has an average distance of 240,000 miles from the earth. On the model it would appear as: diameter: ____ inches at a distance of: ____ inches. The nearest star is about the same size as the sun. Its distance from the sun is 270,000 times the earth's distance. How far from the sun would the nearest star be on the model? You had better give this in miles.

dence, R.I.; San Francisco; Springfield, Mass.; Stamford, Conn.; St. Petersburg, Fla. In each of these twenty American cities there is a planetarium.

In a planetarium, the stars are shown as tiny points of light thrown by a projector onto a ceiling. As the position of the projector is changed, you may view the skies of the whole world for an entire year in a few minutes. A visit to a planetarium is an experience you will never forget.

Signposts in the Sky

The navigator (that is, the man who plans the route) on a ship or in an airplane has no one to point out the stars to him. He must know where to find them. There are 55 special stars known as navigation stars. Let us try to find a few that everyone should know.

Of course, you have heard of the North Star, called Polaris (poh-LAY-riss) because it is almost over the earth's North Pole. To find Polaris, first face north, and then look for the pointers. These are two stars in the outer part of the Big Dipper's bowl. Anyone can spot the Big Dipper because it really looks like a dipper. Look along the pointers of the Dipper across the sky (about five times the distance between the pointers). You will see a fairly bright star (Fig. 59). That star is Polaris. It is the last star in the handle of the Little Dipper.

Once you have found the Dippers and Polaris, you can use them as guides to find some of the other constellations and navigation stars. Let your eye continue on across Polaris, following the line of the pointer stars. Soon you will see a great square of four brilliant stars. This is part of the constellation of Pegasus (PEG-ah-sus), the Winged Horse (Fig. 59). It is one of the plain signposts of the sky, but if you have trouble seeing a horse flying upside down in this constellation, look for a baseball diamond instead. Between Polaris and Pegasus is a W-shaped constellation. This is called Cassiopeia (kas-ee-oh-PEE-ya), the Lady in the Chair (Fig. 59). Soon you will discover that it is easy to find constellations if you know a few of them to use as guides. Try to find some more of the constellations shown in the star charts in Fig. 59.

The Movements of Stars

You may rightly wonder how stars, which appear to be in one place, move. In space nothing is fixed in place, but the stars do seem to be in the same place year after year. The stars you see tonight are in almost the same place they were seen in by the astronomers of Egypt several thousand years ago. The Egyptians thought of the stars as lamps hung in the sky on long ropes. Actually, all the stars are moving very fast. They are traveling across the sky in many directions. Our own star, the sun, is racing toward the constellation Hercules. At present, most astronomers are not fully satisfied with the explanations of why the stars move.

Like the sun, the stars seem to travel across the sky, rising in the east and setting in the west. This is really not so. It is a trick played upon our eyes; the trick is caused by the daily movement of the earth on its axis. It is more like the "motion" of

the telegraph poles we see from the window of a moving car. We know that it is the car that moves; yet we seem to see the poles moving.

Another thing we think we see is the twinkling of the stars. Stars don't twinkle; the twinkling is caused by the movement of the air on the earth. It is like seeing the wall "move" behind a hot stove, a trick played on our eyes by the light as it comes through the hot, moving air.

Stars are so far away that we cannot see them move, no matter how long we look at them. You may be sure, however, that if you ever see something that looks like a star shoot across the sky, it is not a star. What are these things which people call "shooting stars"?

"Shooting Stars"

On any clear night, you can see "shooting stars." These flashes of light are not stars at all but bits of stone or metal. They just happen to fly from outer space into the earth's air at high speed, and this causes them to get red or white hot. Astronomers call these things *meteors* (MEE-tee-erz). Meteors burn up quickly, and while they burn they show up as a streak of light. On the other hand, if the meteors don't burn up, they hit the earth. Then they are called *meteorites* (MEE-tee-er-eytz).

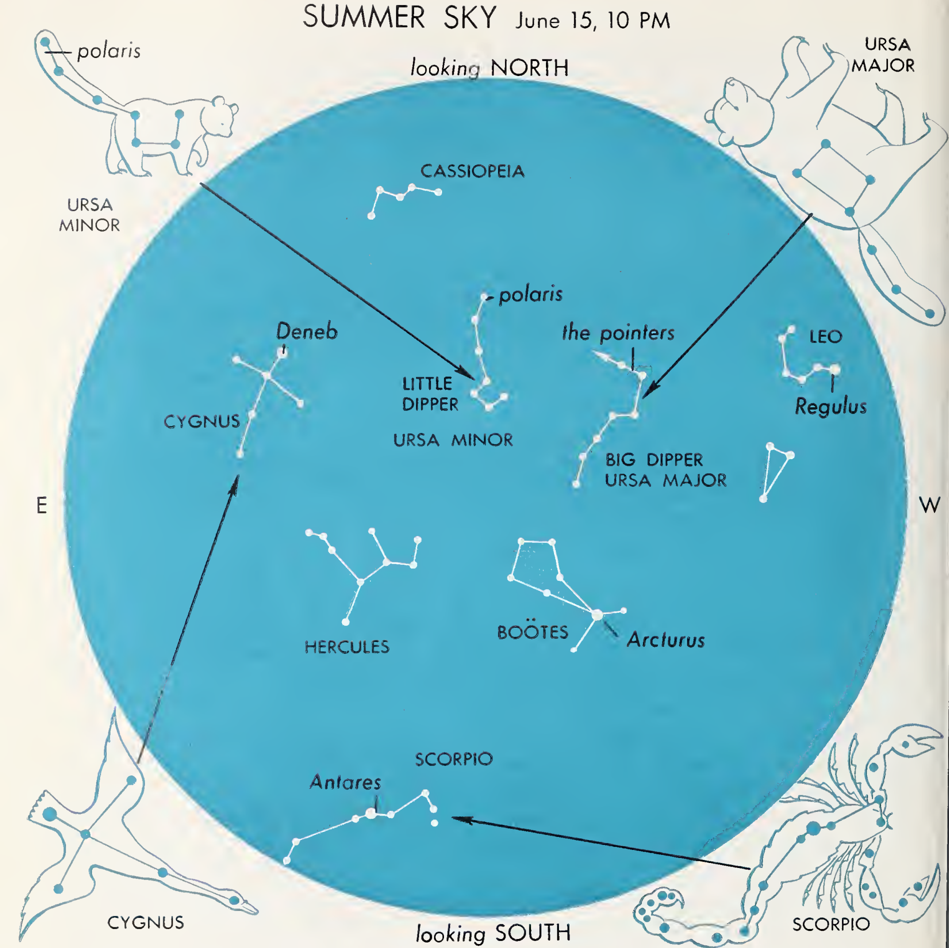
Once in a great while a very large meteorite lands on the earth. If you go to Meteor Crater in Arizona, you will see what happened when a giant meteorite struck the earth long ago. You will see a hole in the ground three-quarters of a mile across and 600 feet deep. Nearby are many pieces of the meteorite. The main piece has never been dug up because it is buried so deep. All around, the rock in which the meteorite is buried is powdered as if it had been hit by an H-bomb. An even larger crater was made in a distant part of Siberia, which is in Russia. Another still larger crater (about 10,000 feet across) was found in 1950 in northern Quebec in Canada.

At present, the largest meteorite in the world on view in a museum is the great Ahnighito (ah-nig-HEE-toh) Meteorite, weighing 36½ tons. It can be seen in the Hayden Planetarium in New York City. It was brought to New York by Admiral Peary, who found it in Greenland. The natives there gave it the name Ahnighito, which in their language means "the tent." This great meteorite is largely iron, but some meteorites are more like stone and a few are rather like glass.

Making a Date with a Comet

No one can promise that you will see a meteor in a certain part of the sky at a certain time. We know, however, that at certain times of the year, such as in August and October, swarms of meteors flash across the sky. These meteor swarms travel around the sun on the orbits of certain comets (Fig. 60). This makes it seem that the swarms of meteors are caused by tiny bits of material that were left behind by the comets as they passed.

Comets have been known since the earliest times. They have tails which stretch millions of miles across the sky. The great comet of 1843 was said to have had a tail 200 million miles long. Halley's Comet, last seen in



59 Look at the night sky in summer or in winter and you will see among the stars certain patterns of light more outstanding than the rest. Observers in the United States will always see the two Dippers and the constellations around them. Other constellations appear, move westward with the seasons, and disappear from view.

1910, had a tail 40 million miles long (Fig. 60). The tail is a glowing mass of gas. It is believed that if all the solid material in the tail of a comet could be pressed together, it would fit into an ordinary suitcase. The earth has passed through the tails of comets many times without the slightest damage. If astronomers had not been able to figure the path of these tails, people on the earth would not even have known that they were passing through them.

If the earth were hit by the head of a comet it would be another story. Some people believe that craters like

WINTER SKY November 15, 10 PM

Shown in the charts on these two pages are eight easy-to-recognize constellations as the ancients imagined them to appear. Shown also are other constellations of summer and winter. How many can you identify? *Project:* If you want to become an amateur astronomer, see the "On Your Own" section on pp. 625–648.

the one in Arizona may have been made by one or more meteorites from the head of a comet. This has never been proven. It is believed that the head of a comet is made up of material like that in a meteor. It is probably not a solid mass, but it may be made up of many small pieces.

A comet's tail fades away as the comet travels farther and farther away from the sun. Its head does not. The head of a comet like Halley's Comet travels on a long, oval orbit. As it nears the sun, the tail grows longer and longer. Why this happens is not known, although there have

MT. WILSON AND PALOMAR OBSERVATORIES

60 Halley's Comet in 1910. Look for it to reappear in 1986. Approaching the sun, the comet grows a tail which disappears as the comet retreats from the sun. *Project:* Organize a "Halley's Comet Club." Learn all you can about the comet and plan to see it together in 1986.

been many guesses. Since the tail always points away from the sun, it is believed that the rays from the sun push the tail farther away from the head of the comet as the comet nears the sun. A halo of light shows at the same time around the head of the comet, adding to the glow it makes.

This bright light around the head of the comet makes it possible for astronomers to track comets as they come toward and go away from the sun. The astronomer who first tracks a new comet usually has the comet named for him. Halley's is probably the most famous of all comets. It was first seen as early as 240 B.C., but not named until 1682, when the astronomer Halley figured its path and stated that it would return in 1758. It came again in 1834 and in 1910 — every 76 years. Add 76 years to 1910 and look for its return in 1986. How old will you be in 1986?

A Model of the Universe

Sir James Jeans, a famous astronomer, once said that there may be as many stars as there are grains of sand on all the beaches of the world. Of course, Sir James had not counted the grains of sand on even one beach. What he meant was that there are so many stars that no one could ever hope to count them. You may wonder what kind of universe can hold so many stars at such great distances from one another and from us.

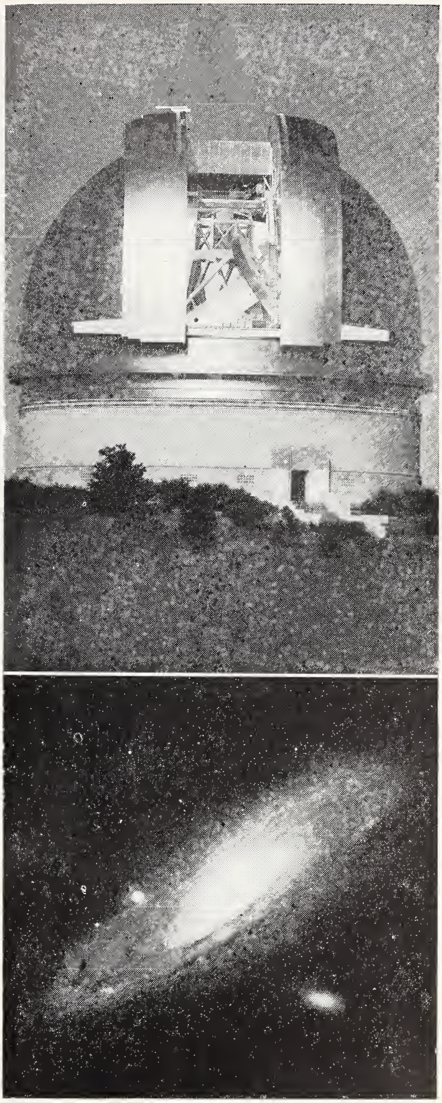
It may help you to think of the model of the universe Dr. Donald Menzel, an astronomer at Harvard, pictures for us in his interesting little book, *Stars and Planets*. He asks us to think of the universe as a great building with square sides each 3,000 miles long and 3,000 miles wide. The floor

of this building would cover all of the United States and Canada, and its walls would rise 3,000 miles into the sky. One hundredth of an inch in this building would be equal to 3 billion miles in the real universe. Remember, no one has yet fully measured this universe.

Dr. Menzel tells us that anyone who might look around inside this building would at first think it was entirely empty. But let us suppose we are standing right in the center of the floor. With a powerful telescope we can see what look like swarms of tiny flies here and there. The largest of these swarms takes up no more space than the state of Rhode Island. Yet each swarm is made up of trillions of stars, many as large as our sun or larger. Each swarm of stars is called a *galaxy* (GAL-uks-ee). There are thousands of these galaxies, perhaps millions of them in our universe. One of them, in which the stars are arranged like a giant cookie with a raisin in the middle, is shown in Fig. 61.

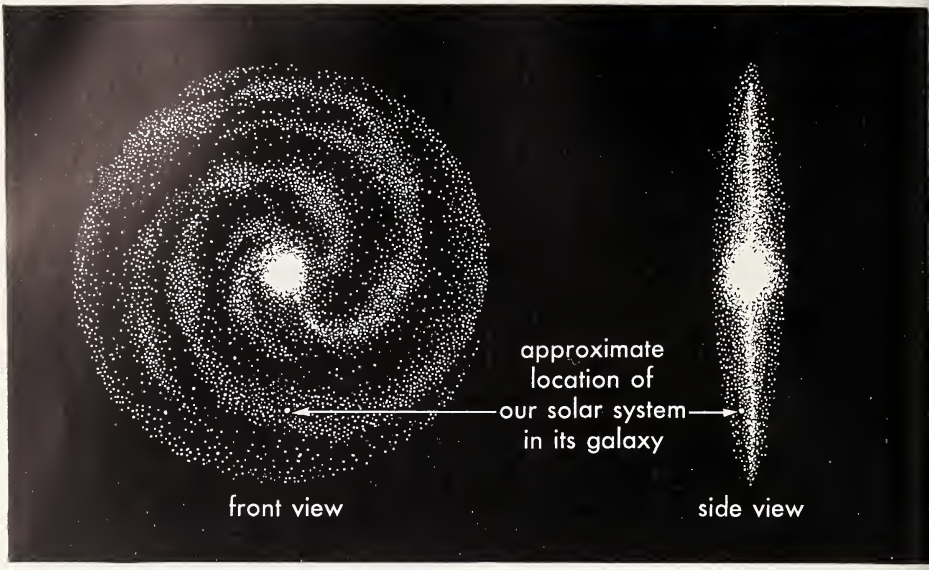
The galaxy to which we belong is thought to look quite like this. It is called the Milky Way galaxy (Fig. 62). Our sun is one of 30 billion or more stars in the Milky Way galaxy. In fact, the name Milky Way came from the milky white path of stars forming the rim of our galaxy which we see in the sky. The billions of stars that form this path are not closer together than other stars. They just seem to be closer because we see them one behind another.

To get a true idea of the size of the universe, you see, is an impossible task. Even an astronomer like Dr. Menzel finds it impossible. His 3,000-mile building is not perfect for two reasons. First, a building has



MT. WILSON AND PALOMAR OBSERVATORIES

61 This great spiral nebula was photographed by the Hale (200-inch) Telescope. It is inside the observatory on Mount Palomar, California. Our solar system is thought to be part of a galaxy (a great spiral of stars) which looks somewhat like this nebula.



62 Our galaxy, the Milky Way, as it might look to someone a million light-years away. At that distance he could not tell the sun and the planets from the other stars. The universe has millions, perhaps billions, of galaxies.

a top, bottom, and sides. But no one knows whether this is true of the universe or not.

Second, since Dr. Menzel wrote this, new information has led scientists to believe that the universe is eight times as large as Dr. Menzel thought. This information was discovered only in 1953.

How truly small is the speck of a planet on which you live! Our universe, mainly space, has in it a great, great number of these swarms or islands of stars. Each of these galaxies is made up of billions of stars more or less like our sun. Our sun, our daytime star, is in one of these galaxies, the Milky Way galaxy. Our earth is one of nine planets circling about this sun. It is but a speck in a universe so vast that no human being can truly understand its vastness.

Yet our earth, speck though it is, has on it the conditions which make life, as we know it, possible.

CONDITIONS FOR LIFE

We know there are five main conditions for life on this earth. If any one of these conditions should change or leave, all life we see on earth would be at an end or at least change greatly. All living things need:

1. Enough oxygen
2. Enough water
3. Proper food
4. Proper temperature
5. Proper pressure

Oxygen and Life

Oxygen belongs to a group of things called gases. Oxygen makes up about one-fifth of all air; the rest of

the air is a mixture of nitrogen and other gases. However, the air you breathe at the earth's surface has more oxygen than the air 5 miles above it. At 18,000 feet, or about 3½ miles above sea level, an airplane pilot (if he were not in a special kind of cabin) would have to take two breaths to get as much oxygen into his lungs as in one breath at sea level. Higher up, fliers find it more and more difficult to get enough oxygen to supply the needs of their bodies.

Without oxygen in the air, all life on earth as we know it would be at an end.

Water and Life

If the earth were too hot, all the water would dry up; and if the earth were too cold, all water would freeze. The fact that the earth is not too hot nor too cold is important to us for many reasons, one of which is that our bodies are about two-thirds water. The water in your body is useful in many ways. It helps to carry food to your cells. Water is one of the daily needs of your life.

If you were without water even for a day, you would understand how much it is needed. If the water on the earth were to disappear, all animals and plants would soon die. Even the camel, which can store up a week's supply, would die. And so would plants like the cactus.

Food and Life

As you remember from your reading in Unit 2, even if you had plenty of water, you would not be able to live for long without food.

Because living things always need food, all kinds of life in all parts of the world must find the right kind of food. Some animals, like cows, sheep, and horses, eat grass or other plants. They live only where there is enough grass or similar food. Other animals, like the lions, tigers, and wolves, are meat eaters. They must, therefore, live near the animals they feed on. Lastly, other animals eat both plants and meat. Because man has used his brain, he has learned ways to keep food — both plants and meat — from spoiling, even though he has to carry it long distances. Thus man has been able to travel far and wide over the face of the earth. Think what would happen to him if there suddenly were no more plants and animals!

Temperature and Life

A healthy human body stays at a temperature of about 98.6° F. Man could not live long in cold or very hot climates without protection against great heat or cold. It is the same with plants and animals. For example, alligators and roses do not thrive in the icelands of the far north, nor do polar bears thrive near the equator. Most plants and animals cannot live where the temperature is too low or too high.

On the earth, there are wide differences in temperature. Higher places on the earth, such as the top of Mount Everest and other high mountains, have bad storms and low temperatures. In Antarctica, during the IGY year, temperatures lower than 100° F. below zero have been recorded. In Death Valley in California, a temperature of 149° F. above zero has been recorded. People who are prepared for such temperatures can live in these places for a short time. However, there are certain tempera-

tures beyond which human life cannot exist, as tests have shown.

The lowest possible temperature is 459° F. below zero. Before this temperature is reached, the air becomes a solid frozen mass. On the other hand, at high temperatures solid things turn into liquids or gases. The temperature of a gas flame, such as that in a gas stove, is 1,100° F.; iron melts at 1,700° F.

Life for us would not last long at 158.6° F., a temperature 60 degrees above 98.6° F., our normal body temperature. Why? Because the bodies of all animals have in them materials like the white of an egg. These materials are called proteins. The proteins in your body would change much as the white of an egg does in boiling water if you were to remain at a temperature above 158° F. even for a short time.

A human body without protection would become like ice and solid at 23° F. (or just 9 degrees below the freezing point of water). Only by using heating and cooling systems can man stay alive at very high or very low temperatures.

Pressure and Life

You may hear people say that it is hard to live under the pressures of today. They mean the strain of all the things they have to do or worry about. This is not the kind of pressure a scientist has in mind. He means the kind of pressure that happens when something pushes against something else. For example, by pushing on a brake pedal a driver of a heavy truck can bring the truck to a stop. The barber or dentist with a push of his hand or foot raises you in a chair by the same method. The pressure of air in the tires of an airplane allows it to land gently.

You yourself are under the pressure of air all the time. The weight of all the air in the atmosphere pushes upon your body in all directions with a pressure of 14.7 pounds per square inch. As long as the pressure on the inside and outside of your body is the same or nearly so, you can forget about pressure. Deep-sea divers and pilots of airplanes at high altitudes have to think about keeping the air pressure around their bodies just right (Fig. 63).

Animals that live in water are under a greater pressure than are animals that live in the air. At a depth of only 34 feet the pressure of water on the body is twice the pressure of air at sea level. A fish living one mile down in the ocean is under a pressure of over one ton per square inch. Yet this great pressure outside is balanced by an equal pressure inside the fish's body. When a deep-sea fish is hauled up quickly from the ocean, its body swells. This is because the greater pressure inside its body is no longer matched by the lesser pressure of the water near the surface.

To be able to stand the pressure of water, divers usually wear special suits into which air is pumped. As they breathe this air, the pressure inside their bodies becomes greater. Like the fish, they will have trouble if they are brought up to the surface too quickly. Bubbles of nitrogen form in the blood and gather in the joints if a diver is brought to the surface too fast. This causes him to have great pain and bleeding, which may result in his death. Read Commander Ellsberg's book, *On the Bottom*, if you want to get a better idea of how high water pressures act upon divers.

U.S. NAVY

63 Spacesuits, like this one made for the U.S. Navy, can withstand lowered air pressure, permit normal breathing, and yet allow a good deal of freedom of action so that a person can work.

Even without doing any diving under water, you can find out how changing pressure feels. Did you ever ride up in an express elevator in a tall building? If so, you may have had a queer feeling inside your ears. When you swallowed hard it went away. That feeling was caused by the change in the air pressure. Makers of high-flying passenger planes now build the cabins so they can be sealed before the planes leave the ground so that the air pressure will remain the same during the flight. Such cabins are called "pressurized" because the air pressure is kept at the right amount for the passengers' comfort.

Conditions on Our Planet

These then are the five conditions needed for life as we know it. Every animal and plant on earth needs the right amounts of oxygen, water, and food. They also need the proper temperature and the proper amount of air pressure. Whether the living things we find on earth can live on other planets depends on whether these conditions for life are present. This is important to know before starting out on a space trip.

Conditions on Other Planets

What are the conditions scientists have been able to discover on other planets? Let us start with the planet nearest to the sun.

Mercury has no blanket of air. As it goes around the sun, it always presents the same side to the sun. The temperature of the sunlit side is always about 700° F., which is above the melting point of lead and about 500° F. above the boiling point of water. Its dark side is too cold to measure, but it is probably close to −459° F. Can you think of any form of life able to remain alive under such conditions?

Venus is a planet whose surface cannot be seen from the earth. This is because it is covered with clouds that are so thick we cannot look through them. We do not know what these clouds are made of, but we do know that there are great amounts of the gas carbon dioxide in them. If there is carbon dioxide near the surface of Venus, life as we know it at present could not exist there. The temperature of the upper atmosphere of Venus is about −50° F., which is close to the temperature of our

YERKES OBSERVATORY

64 Mars has markings which show seasonal changes of color, and polar ice caps that change in size. Do people live there? We don't know. *Project:* Write an article for your school paper or magazine titled, "Are There Men on Mars?"

earth's upper air. Whether there is life on Venus is an open question without an answer as yet.

Mars may be the first planet man will try to explore. It has an atmosphere, but it is thin. For this reason we can see and study the surface of Mars (Fig. 64). It is known as the red planet, but the color of its surface seems to change to green at times. This seems to point to some kind of plant life that changes with changes of season. In its polar regions there are white areas that change in size. This seems to show that there is water and ice or frost on Mars.

Through a telescope a network of dark lines can be seen. These are called "canals," but few scientists believe they are the kind of canals people might have built. Mars has no oceans, and the amount of oxygen in its atmosphere is very small. The temperature of Mars seldom rises above 50 or 60° F. at its equator, but may reach 80° F.

Can there be life under such circumstances? The astronomer Lowell said that the markings and changes of color show there is life on Mars. Few astronomers are ready to agree with him, but they will admit that they cannot prove him to be wrong.

Jupiter, *Saturn*, *Uranus*, and *Neptune* are giant planets much larger than the earth. There is little hope of anyone's ever visiting these planets because no way is now known to avoid a crash landing that would destroy man and his rocket. The force which holds things to the surface of these planets is much greater than the force which holds things to the surface of the earth. And even if a safe landing were made, this same pull would make an escape for a return trip to the earth very difficult.

Living conditions on these giant planets would probably be very bad for living things such as those we know on earth. Temperatures are very cold on all of them because they are so far away from the sun. Jupiter, the warmest, has a temperature of about −202° F. The air of the giant planets has no oxygen, but much ammonia and marsh gas.

Now that you have the main facts, would you say that life as we know it can be found on other planets? Most scientists say that, if there is life on these planets, it has the best chance of being found on Mars or Venus. Can you see why from the facts you have just read? It is also believed that, if there is life on these planets, it may not be at all like life on the earth. We shall have to wait for more direct proof, such as the reports of space explorers who reach these planets and come back with real samples and

photographs. Till then we can only guess and make theories.

OUR SUN AND THE PLANET EARTH

We do not need to make theories about the conditions which make life possible on the earth. Besides having the five things named before, we have just about the right amount of heat and light, which we get from the sun.

Of course you know that the amount of heat and light the sun sends to any one spot on the earth is always changing. It changes from hour to hour, from day to day, and from season to season. These changes take place because the earth is in motion and because the earth's axis is slanted. To give you an idea of the relation of the earth to the sun, do this experiment yourself.

The Earth's Share of Sunlight

Let a large ball (or globe) be the earth, and a small electric light bulb be the sun. Go into a darkened room, which will represent space. Now light the bulb, and hold the ball (or globe) in its rays.

Notice that no matter how you hold it, one half of the ball is always in darkness and the other half always in the light.

Remember that the sun, like your light bulb, gives out heat and light in all directions at the same time. The entire earth catches only a billionth part (0.000,000,001) of all the heat sent out by the sun. How fortunate this is! Can you guess what would happen to us if the earth were to receive two, three, or ten times as much heat? Or suppose we were to get only one-half, one-third, or one-tenth as much. What would become of us? If we were to get much more, we would be burned to a crisp. If we were to get much less, we would freeze.

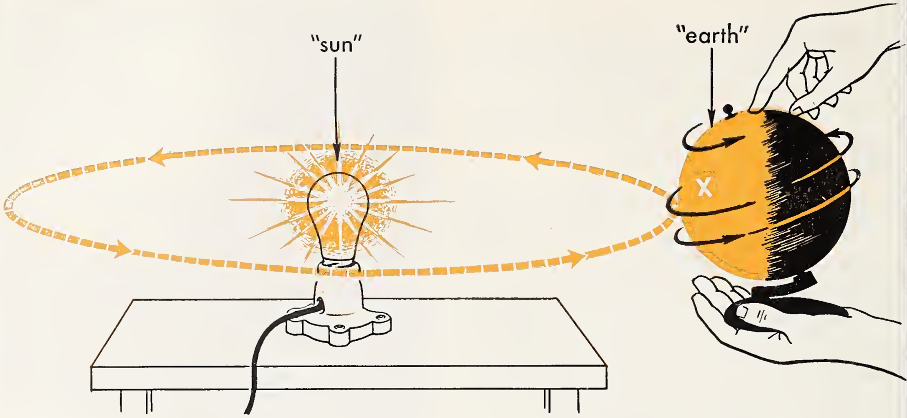
Hold the ball four inches from the light bulb. Don't move the ball. Place the bulb of a thermometer between the ball and the light bulb, close to the ball. Place another thermometer against the darkened side of the ball. What is the difference in temperature? The lighted side is always warmer.

The situation is similar to what would happen if the same side of the earth were always turned toward the sun. The lighted side would be too hot for most forms of life. The dark side would be too cold. Actually, the difference in temperature between the two sides of the earth would be far greater than in this simple experiment. The difference might be like that found on the planet Mercury (p. 149). But fortunately for living things, the earth turns. Its motions give us the hours of daylight and hours of darkness, and also the changes of season, as you will find in Chapter 12 of Unit 4.

Sunlight and Shadows

It is easy to see how the two motions of the earth give us days and nights of changing length.

Place the bulb (sun) in a lamp on a table. Carry the ball (the earth) all the way around the lamp. The earth takes about 365¼ days to make this kind of journey around the sun, and, as you learned (p. 135),



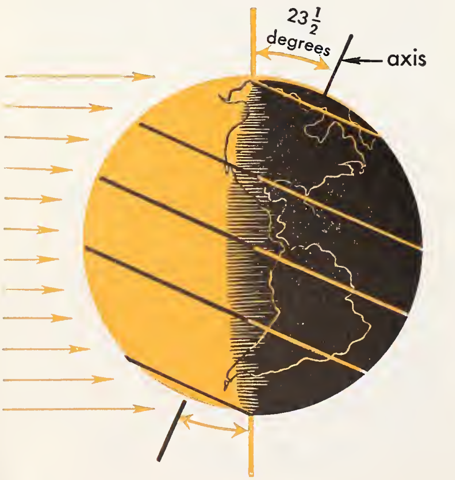
65 Day and night mean sunlight and shadow. If X marks the spot where you live on the earth, the time shown is afternoon. The turning (rotating) earth will soon carry spot X into the shadow, away from the light, and then it will be night for a while. *Project:* Make a model of the earth and sun. With it show how sunlight and shadow mean day and night.

we call this length of time a year. This yearly revolution of the earth around the sun is just one of the earth's motions.

To see another of the earth's motions, put a chalk mark on the side of the ball nearest to you. This chalk mark shows about where you live. Go on walking (revolving) around the lamp, but now twist (rotate) the ball with your fingers at the same time. It takes the earth 24 hours to rotate once and, of course, we call this length of time a day. Notice that the chalk mark you made is carried by the rotation of the earth from the lighted side to the dark side and back again into the lighted side. When the chalk mark is in the light, it is in "daytime"; when it is in the dark, it is in "nighttime" (Fig. 65).

Day and Night

Here are two changes you may always be sure of. Day always changes into night, and night always changes into day. This is because the earth is round and because it rotates. As you can see by looking at your ball and



66 The earth spins on an axis (an imaginary line through the earth from the North Pole to the South Pole) which is tilted at an angle of $23\frac{1}{2}$ degrees. Shown here is the position of the earth in relation to the sun on December 21.

lamp, the sun's light can strike only one-half of the earth at any moment. As the earth turns (rotates) from west to east, new points on the earth's surface come into the light of the sun. If you were in Chicago and looked east at early dawn, you would see the sun seem to rise as the city of Chicago turned eastward. At evening, if you were to look toward the west, the sun would seem to go down and disappear. This would happen because Chicago had turned farther eastward. Day and night and sunrise and sunset are due to the earth's rotation. You can see best how the earth rotates by turning a globe on its axis. Of course there is no real axis, such as you find in the center of a classroom globe, running through the center of the earth. However, it is well to think of the earth as actually spinning on an axis through its center from the North Pole to the South Pole. You may think of the earth spinning like a top.

Different Lengths of Days and Nights

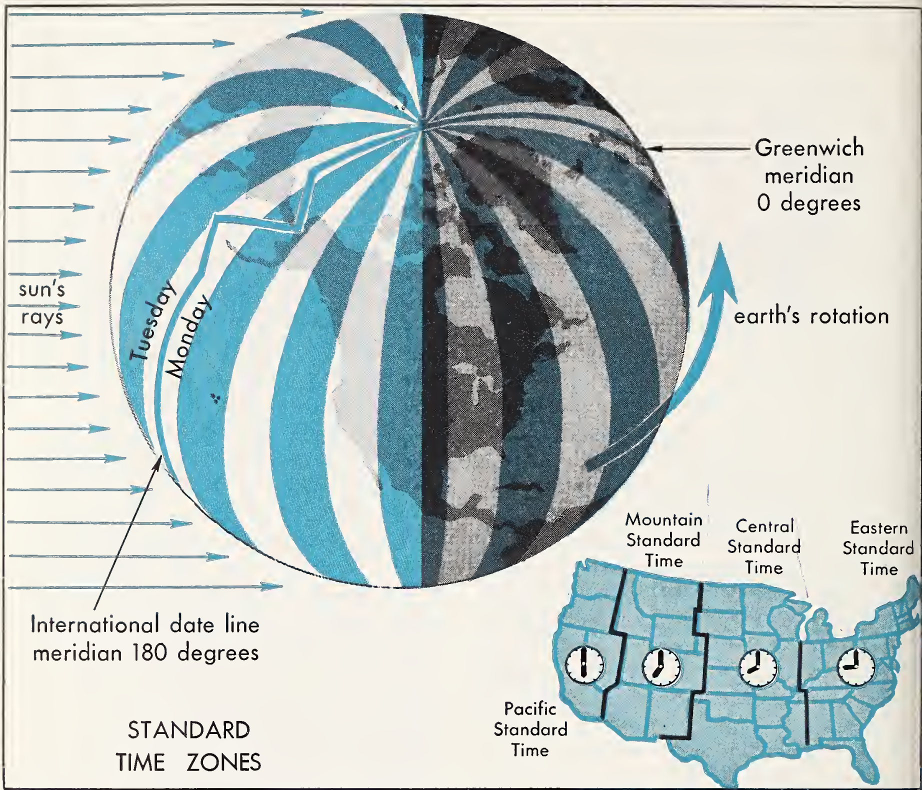
Have you ever wondered why the globe at school or in your home is tipped away from an upright position? Scientists have found that the earth is tipped on its axis like a leaning top. Globe maps of the earth are tipped in the same way to show that this is the position of the earth as it rotates on its axis and at the same time revolves about the sun. The tilt of the earth's axis is 23½ degrees (Fig. 66).

The tilt of the earth's axis is one of the causes of the change in the length of the hours of daylight and darkness as one season follows another. Notice that, as the earth revolves in its orbit around the sun, the South Pole is brought into a position toward the sun during December. This gives the southern half of the earth more direct rays of sunlight for a time. It is then summer in the Southern Hemisphere (Fig. 66). Slowly the earth moves on around the sun until the North Pole is in a position toward the sun during June (Fig. 66). Now the northern half of the earth gets more direct rays of sunlight for a time. It is summer in the Northern Hemisphere.

There are more hours of daylight on the half of the earth that tilts toward the sun. This explains why the days grow shorter for half a year and longer for half a year. The length of the day and other seasonal changes you will study later are the main cause of seasonal weather. You will find the full explanation of daily and seasonal changes in Unit 4, "Understanding the Earth's Weather." Right now just keep in mind that the earth's rotation causes day and night, and that the earth's revolution about the sun together with the tilted axis changes the length of days and nights.

Hours of the Day

Timekeeping is important to the whole world. Therefore, to learn about the kind of time we keep you must first know a bit about the time zones into which man has divided the globe of the earth. Since time changes as the earth spins from the west to the east, it is the way the earth is divided in these directions that interests us. Let us pretend the earth is an orange with the skin off. You know how each section of the orange seems to be divided from the next one by lines from the top to the



67 The earth is shown here at a time of an equinox (equal hours of daylight and of darkness). Each of the twenty-four bands is a time zone 15 degrees wide. Four of these cover the United States. In which time zone are you located? Why was the international date line placed in the Pacific?

bottom. On the earth such lines, though imaginary, are drawn from the North Pole to the South Pole. They are the lines of *longitude* (LON-jih-tood). They are also called *meridians.* There are 360 meridians, each separated by one degree.

In 1884, at the Washington Meridian Conference, the nations of the world agreed to divide the earth into time zones based on lines of longitude 15 degrees apart (Fig. 67). Since 360 divided by 15 equals 24, you can see that each time zone marks one hour of a day's time. As the earth rotates, approximately one hour passes for every 15 degrees of the earth's surface that goes by a given point. In 24 hours the earth makes one rotation.

It was also decided that the meridian of the city of Greenwich (GREN-ij), England, would be the meridian of 0 degrees longitude. All meridians east of Greenwich up to longitude 180 degrees are called *east longitude;* all meridians west of Greenwich up

to 180 degrees are called *west longitude* (Fig. 67).

Philadelphia is at 75 degrees west longitude, that is, five time-meridians west of Greenwich. Thus there is a difference of five hours between the clocks of Philadelphia and those of Greenwich. Since Philadelphia is always moving eastward to the point in space that Greenwich has been in, Philadelphia time is always five hours behind the time of Greenwich. In other words, when it is two o'clock in the morning in Greenwich, England, it is five hours earlier, or nine o'clock of the night before, in Philadelphia (Fig. 67).

Time Zones in the United States

Time kept according to this world agreement is known as *standard time.* Every fifteenth meridian is roughly the center line of a zone of standard time. Four of these time lines, beginning with the 75th, fall within the borders of the United States and Canada. The others are the 90th, 105th, and 120th (Fig. 67). Therefore, there are four standard time zones covering the United States. On the map you will see that these time zones do not follow even lines. These irregular borders of the time zones were needed to avoid dividing large cities into two zones. As you can see, this would have annoyed many people.

As you study the map in Fig. 67, you will see that Central Standard Time (CST) is one hour earlier than Eastern Standard Time (EST). The next zone is Mountain Standard Time (MST), which is one hour earlier than CST. The last is Pacific Standard Time (PST), one hour earlier than MST. These time zones must be allowed for when you tune in a distant radio program or when you travel east or west beyond your own time zone. In New York when it is 3 P.M. EST, it is just noon PST in California. That is why people in California may be having lunch while listening to an afternoon broadcast from New York. People who travel westward set their watches back one hour whenever they cross the border of a time zone. Going eastward, people set their watches ahead each time they enter a new standard time zone.

The International Date Line

You know now how standard time is kept from Greenwich, England, westward to the Pacific coast of North America. Now suppose you wanted to keep on going toward the west across the Pacific Ocean. You would continue to set your watch back one hour every time you entered a new time zone. If you started at 7 A.M. EST on Tuesday and flew fast enough, you might expect to get back to Monday's evening hours. Then as you flew on and on you would keep going back into past time. This, you see, would be impossible for day-to-day living. There has to be a place where the time can be changed to take care of this. By agreement it is in a part of the world where it will cause the least trouble. Few people live near the 180th meridian, and so it is roughly the *international date line.* Where people do live along this meridian, the date line zigzags a bit like some of the time zone border lines (Fig. 67).

The nations have agreed that a day is to be added to the calendar by

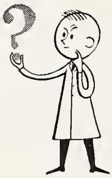
those who cross this line traveling westward. If it is 11 A.M. Tuesday when you cross the date line going west, it will be 11 A.M. Wednesday the next moment. But if you are traveling from China to the United States (eastward) and the time is 11 A.M. Tuesday when you reach the line, it will be 11 A.M. Monday when you cross it. By making these changes, traders on both sides of the Pacific can keep their business calendars accurate.

Daylight Saving Time

In most parts of the United States, we set the clocks ahead one hour at a certain time in the spring of the year. This "fast time," as some call it, is better known as Daylight Saving Time. For about five months when the days are longest, Daylight Saving Time gives many workers an extra hour of daylight after their working hours. It gives them time while it is light to tend their gardens or enjoy some outdoor fun. It also saves electricity that would be used to give light. The idea has spread to Europe, where some of the countries now use Daylight Saving Time. What do you think of Daylight Saving Time?

And Now

On this planet Earth more than a million kinds of living things are to be found. One of them is man. There are now more than two billion people on the earth. Some of them have an idea they would like to explore other planets and the moon. We do not know whether they will be able to travel through space and return safely. But we do know that first they will have to learn about the make-up of the earth, our planet home. This is what you will do when you read Chapter 8.



LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

orbit	light-year	meteor
solar system	galaxy	meteorite
revolution	constellation	comet
planetoid or asteroid		

1. a kind of heavenly body which grows a long, cloudlike tail as it nears the sun
2. any one of the 88 groups of stars and the area of the sky in its vicinity
3. the sun and its family of planets, their moons, meteors, and comets
4. the distance which light, traveling at 186,000 miles per second, travels in a year
5. a heavenly body which glows for a moment as it passes through the upper part of the earth's atmosphere
6. a meteor that has landed somewhere on the earth's surface
7. one of a group of small planets whose orbit is between Mars and Jupiter

8. a single trip of a heavenly body around another heavenly body
9. a star system or cluster of stars
10. the path of one heavenly body as it revolves about another heavenly body

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. Ptolemy taught that the earth is at the center of the . . . .
2. The orbits of the planetoids lie between the orbits of the planets Mars and . . . .
3. . . . of the planets have moons.
4. In all, there are . . . moons.
5. Our sun is an average of . . . miles away from us.
6. The stars are so far away we have to measure their distances by . . . .
7. Our solar system belongs in a swarm of stars known as the . . . .
8. Our present ideas about the solar system are based on the work of . . . , who died in 1543.
9. No one has ever seen the surface of the planet Venus because . . . .
10. The comet that will appear again in 1986 is called . . . .

GOING FURTHER

In the Laboratory and Field

1. *Using your watch as a compass.* When you do this experiment, be sure that the sun is shining. Place the watch on a horizontal surface. Turn the watch until the hour hand is pointing toward the sun. Now place a small stick or toothpick in such a way that it will divide into two equal parts the number of minutes on the dial between the hour hand and the number 12. The small stick will lie approximately north and south. For example, if the hour hand is at 10 A.M., your stick will be laid across the numbers 11 and 5. The number 5 will point to north. Remember, the hour hand must point toward the sun.

2. *Finding your way by the stars.* The next time you go on an overnight hike, plan a treasure hunt with some of the directions based upon the location of certain bright stars or well-known constellations. For example, instead of saying "go north" say "go in the direction of Polaris."

3. *Finding where the sun sets.* Select a good spot near your home where you can see the sun go down behind buildings or trees of different kinds. For one year, at the 1st and 15th of every month, make a note of the position of the setting sun as seen against these landmarks. Does the sun always set in the exact west? When is it north of west? When south of west? By this we mean the exact west. The facts you gather will give you the answer.

4. *Model of a planetarium.* If you have no real planetarium in your city, you may want to make a small model of your own. One way to do it is to get a large tin can into which you punch tiny holes. If you place a light bulb inside the can

and darken your room, you will be able to see spots of light that look like the familiar constellations. There is a fine set of directions for building this kind of tin can planetarium in the November, 1950, issue of *The Science Teacher*, pp. 180–183. Your science teacher may have a copy of this magazine.

Put on Your Thinking Cap

1. If it were suddenly announced that life had been discovered on Venus or Mars, what facts would you need before you would believe the report to be true?
2. Life on the earth might be greatly changed if only a few conditions were changed slightly. Explain this statement.

Adding to Your Library

1. *Beginner's Book of Astronomy* by John Sternig, Taplinger, New York, 1958. A book for young people and adults who are seeking adventure in the universe about us.
2. *The Telescope* by Harry Edward Neal, Messner, 1958. This is the story of astronomers who created their own "fingers to the sky."
3. *The Stars Above Us* by Ernst Zinner, Scribner, 1957. Do you know the difference between astronomy and astrology? This book tells you all about both. This is a book about understanding science and superstition.
4. *The Amateur Astronomer* by Patrick Moore, Norton, 1957.
5. *Earth, Moon and Planets* by Fred L. Whipple, Grosset, 1958. This contains the latest information on planets, their atmospheres and the possibilities for life outside the earth.
6. *Exploring Earth and Space* by Margaret O. Hyde, McGraw, 1957. This is the story of the IGY (International Geophysical Year) told simply.
7. *The World in Space* by Alexander Marshack, Nelson, 1958. Briefly and dramatically this book gives the background and development of modern science. This is another story of IGY.
8. *The World of Copernicus* by Angus Armitage, Mentor, 1951. Here is told the life and work of the first of the great modern astronomers.
9. *You and Space Neighbors* by John Lewellen, Childrens Press, Chicago, 1953. You will enjoy reading this book so much that you will be surprised at the number of solid facts you will get from it.
10. *Astronomy*, Merit Badge Handbook, Boy Scouts of America, New Brunswick, N.J. A well-illustrated booklet for the student scout who is serious enough about astronomy to want to earn a merit rating.

A Bit of Research

You can get from the Maryland Academy of Sciences a "Graphic Time Table of the Heavens" which will help you to find out when many of the interesting things will happen in the sky. This time table is published every year in the January issue of *Sky and Telescope*. You can, for example, find out when planets will be morning or evening stars. Times of sunrise, sunset, and the phases of the moon can also be found on this time table, along with many other interesting facts about the events of the year in astronomy. The address of the academy is Enoch Pratt Library Building, 400 Cathedral Street, Baltimore 1, Md.

Careers for You

Do you think astronomy is only for scientists? If so, read "On Your Own" at the end of the text and do some of the projects. Besides being a fine hobby, astronomy is an important tool for those who guide ships and airplanes on their way. There are good jobs waiting for good *navigators*, but you cannot become a good navigator without knowing some astronomy.

CHAPTER 8

Our Planet Home — and Its Moon

Look at the moon any clear night. It will be some 238,000 miles away. In ocean tides and eclipses the moon plays a part in your life. And the moon may be the first outpost man will reach in space.

Exciting as it may be to think about exploring the moon, we must first explore the earth, our planet home. Of course, men have been exploring the earth since earliest times, and you may think there is very little left here to explore. We really do know a great deal about the earth, but there is much more to be discovered. The earth, you see, is not just the land on which we stand. Part of it is the air envelope, the *atmosphere*, that surrounds our planet. Part is the oceans, seas, and rivers. Part of our earth is the mass of very hot rock below its surface. In spite of the wonderful discoveries that have been made, there are still many unsolved problems for which we have not found the answer. What science has found out and what science wants to find out about our planet is the story of this chapter.

Let us begin our journey by looking at Fig. 68, which shows the earth like a ball that is slightly flattened at the poles. The earth's average diameter is about 7,920 miles. This means that it is about 3,960 miles from where you are now standing to the center of the earth.

You really are standing at the bottom of an ocean of air, the exact depth of which no one knows. Scientists believe that a tiny amount of the gases that make up the air may be found 600 miles or more above the earth's surface.

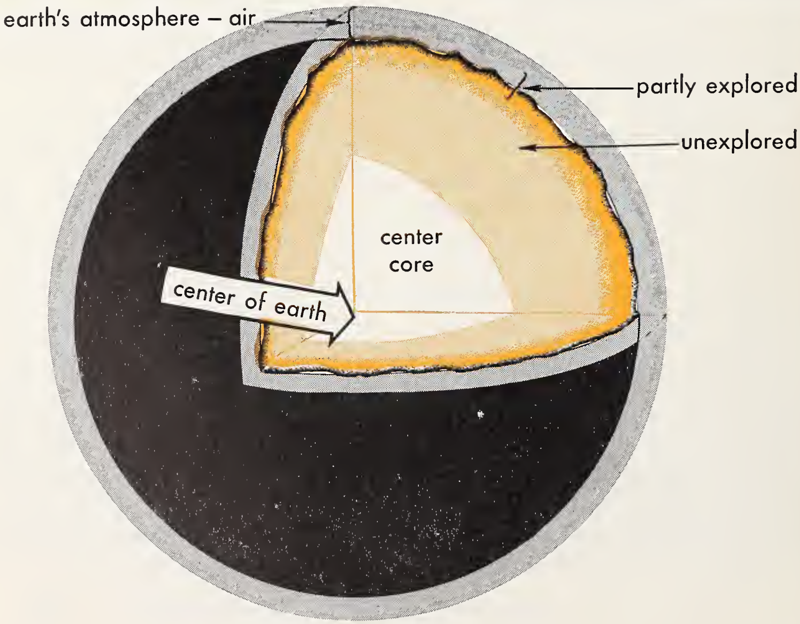
Roughly 70% of the earth's surface is covered by bodies of water, the largest of which are the oceans. Their average depth is about 2 miles, but the deepest part of the ocean is a mile deeper than Mt. Everest is high. This is the Emden Deep, sometimes called the Mindanao (min-duh-NAH-oh) Deep. It is off the east coast of Mindanao, one of the Philippine Islands. Mount Everest, the world's highest mountain (29,002 feet), was climbed successfully for the first time on May 29, 1953, by Sir Edmund Hillary and Tenzing Norkay. But the lowest depth to which a man has gone down into the sea was the descent of 13,288 feet made by the two French naval officers Houot and Wilm in 1954. These men and others were pitting themselves against the forces which rule our unstable earth.

OUR UNSTABLE EARTH

You may wonder how anything as solid and hard as a rock can be changed. You may think that since the earth is so very old it should be firmly set and done with changes. This is not so. The earth moves, shakes, and changes. You have heard of some of the things that happen, such as earthquakes, volcanoes, and dust storms. Now you are going to learn more about them and the forces which rule our earth.

Earthquakes

Look at the map in Fig. 71. It shows you what is often called "the



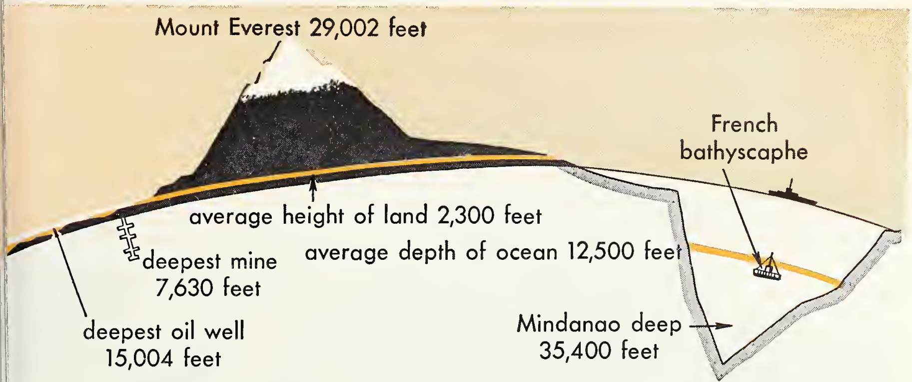
Earthquake Belt." It might also be called "the Volcano Belt." Most of the active volcanoes and most of the great earthquakes happen within the colored areas on this map. You can check this for yourself if you have an almanac like the *World Almanac.* Look up "Earthquakes" and find out where the most important ones took place. You will see that nearly all were within the colored belt shown on the map in Fig. 71. If the newspapers report an earthquake, check its location on this map to see if it is in the "Earthquake Belt."

Between the years 1899 and 1923, 1,783 great earthquakes happened within the colored area on this map. One dangerous belt almost circles the earth near the middle, and the other danger zone almost surrounds the Pacific Ocean. Remember that these 1,783 earthquakes were major quakes. An instrument that records earthquakes is called a *seismograph* (SYZE-muh-graf). A major earthquake is one strong enough to be felt on seismographs in widely separated places. In New England, for instance, over 500 earthquakes take place each year, but only a few of them even cause rattling of dishes on the kitchen shelves. Another 100,000 quakes (barely felt) probably happened during the same twenty-four year period from 1899 to 1923.

THE CAUSES OF EARTHQUAKES

Have you ever tried to lift a rock or boulder the size of a basketball? Rather heavy, wasn't it? Now try to imagine the tremendous weight of a pile of rocks a mile high — five miles high — fifty miles high! Down inside the earth at depths from five to fifty miles the total weight of the rocks is the cause of tremendously heavy pressure.

This pressure causes cracks or



68 *Left*, men have explored most of the land and water of the earth's surface, but they have gone only a few miles into the interior of the earth or beneath the sea. The upper atmosphere is still unexplored. *Above*, a cross section showing the greatest heights and depths of the earth's surface.

69 Faults in rock formations are deep cracks that go down through many rock layers. When sections of rock slip along such cracks, the earth shakes and quakes.

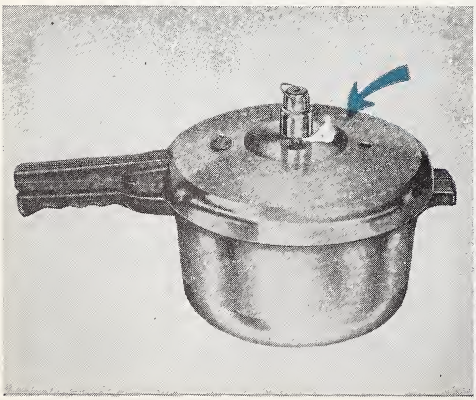
faults which may go for several miles into the depths of the earth (Fig. 69). Suddenly a whole section of the rocks gives way under this pressure and slips a short distance downward or sideward along one of the faults. This movement sets up vibrations called *shock waves.* These waves travel outward in all directions like the ripples on a pond when you toss in a stone. Shock waves travel upward, downward, and sideward. Thus they may be measured with instruments thousands of miles from the point on the surface where the earthquake is causing its worst damage.

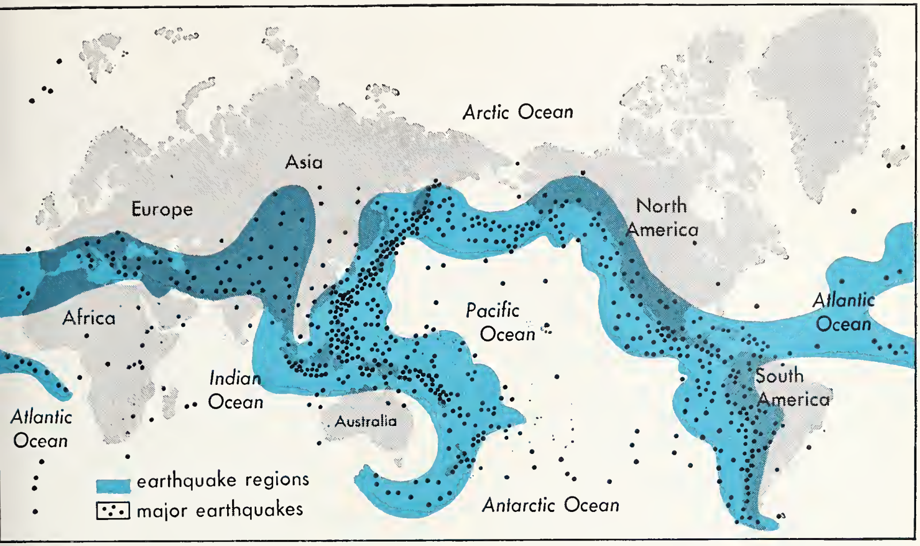
To give you an idea of the great damage an earthquake can cause, consider the one that struck the Shensi (shen-SEE) Province of China in January, 1556. Entire villages, disappearing like toy houses in a box of sand, were buried by the loose, moving soil. The Chinese said that the mountains seemed to walk. This disaster took the lives of several hundred thousand people. In the summer of 1949, an earthquake in Ecuador destroyed several villages and took the lives of some 4,000 people. In 1953 and 1954, several major quakes shook the islands and mainland of Greece. Buildings crumbled. More than 1,000 people were killed and about 130,000 were made homeless.

Usually the greatest destruction is caused in the region right above the spot where the rockslide has taken place within the earth. If the earth-

70 The eruption of volcanoes like Parícutin (pah-REE-koo-teen) in Mexico is like release of steam from the safety valve of a pressure cooker. The eruption is alarming, but imagine how much worse it would be if the container (the earth or the pot) blew apart!

NATIONAL PRESSURE COOKER CO. AND DEATHERAGE FROM MONKMEYER





71 The "Earthquake Belt" encircles the earth near the equator, but it also nearly encircles the Pacific Ocean. Earthquakes take place most often where the mountains are still rising. *Project:* Make a map like this one and place it on the bulletin board. Keep a record of earthquakes as they are reported by placing a pin on the map where they took place.

quake happens beneath the ocean, it sets the ocean in motion. The result is a huge ocean wave, often called a *tidal wave*. Sometimes seacoast villages hundreds or thousands of miles away may be destroyed when the great wave sweeps over them hours later. Such a tidal wave struck Hawaii in the winter of 1948. Many villages were destroyed.

Volcanoes Are Safety Valves

An earthquake can take place anywhere, but you do not expect ever to be bothered by a volcano unless you happen to be near one. A volcano is a crater or hole leading down like a chimney into the earth at a spot where the rock crust is weak. In a volcano, melted rock and cinders are near the earth's surface, where they may be blown out over the nearby land.

Most of the active volcanoes lie within the great earthquake belts. Because of this, some people jump to the conclusion that volcanoes are the common cause of all earthquakes. It is true that volcanoes sometimes cause small earthquakes in their immediate neighborhood. Remember, however, that rockslides deep down in the earth cause most of the great quakes.

Although volcanoes cause only small earthquakes, do not for that reason think that they are safe companions. A volcano erupting is very, very dangerous to all living things. Flying boulders, syrupy streams of flaming lava, fiery cinders which fall like rain, and deadly clouds of hot, poisonous gas are all part of the eruption.

If a volcano began to erupt in your backyard or pasture (as Parícutin did in west central Mexico a few years ago), you would probably not think of it as useful. Nevertheless, a volcano on the earth is like the safety valve on a pressure cooker. Once in a while when the steam pressure gets too high, the valve blows out. Volcanoes allow the great pressures that build up inside the earth to escape, and thus they prevent much greater destruction.

Having read of the destruction these upheavals cause, you may be surprised to know that many scientists think that earthquakes and volcanoes are valuable to man. Where they occur, you will find the highest mountains and the richest minerals in the earth. When rocks shift, when volcanoes erupt, new materials are brought to the surface. These materials can be used by man.

In addition to earthquakes, there are other forces which build up land and still others which tear it down, as you will see.

Weathering and Erosion

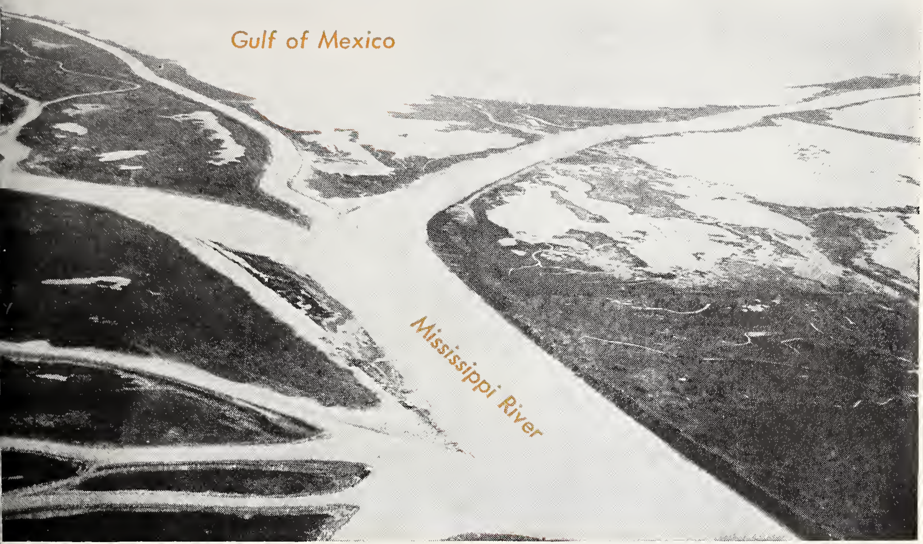
People who live in houses close to the ocean, or along the banks of a big river, or on the side of a mountain, or on a farm in the Dust Bowl know that the forces of weathering and erosion are real and dangerous. They cause landslides, dust storms, and floods. Such things can be as fearful and damaging as earthquakes and volcanoes in eruption. We are likely to forget that weathering and erosion are at work twenty-four hours a day.

Weathering is the action of the sun, wind, water, ice, and rain upon the earth, wearing it away. *Erosion* is another word used to describe wearing away. *Erosion* is used in speaking of the wearing away of soil by wind and water.

The men who keep big bridges painted, like the George Washington Bridge in New York or the Golden Gate Bridge in San Francisco, are never finished. If they do not repaint these bridges every few years, the bridges will be destroyed by the action of the weather. Every homeowner faces the same problem. He must work all the time to hold the line against the forces that little by little might destroy his property.

Wind and rain and changes of temperature cause the kind of weathering we must fight. Every bare hillside shows the effect of the rain. Look at any bare slope after a storm and notice how water may have worn away some of the soil. Even in city streets the leaves and twigs that stop up the sewer drain show that weather and erosion are at work.

To make this problem real to you, look about your home or school for damage which is being done by weathering and erosion. You might start with the windows. In almost any house you will find some windows that are dangerously loose because the putty has come away from the glass. Notice the wood on the inside and outside sash of such windows. Has it begun to crack or rot? Is this due to rain or snow? Make a list of the places where repairs are needed so that weathering and erosion will cause no more damage. Do not forget the walks and the roof. Look at the condition of exposed hinges, too. Discuss with your parents or handyman the importance of doing whatever is necessary to prevent further damage.



NEW ORLEANS DISTRICT CORPS OF ENGINEERS

72 The Mississippi delta is land built up by the river from soil the river took from land upstream. Water is a builder as well as a destroyer of land. What other rivers that you know have deltas?

Wearing Down the Earth

The wind carries sand, which rubs and scratches the surfaces of the earth like a file or a piece of sandpaper. Water seeps into the scratches and cracks in rocks. In winter this water becomes ice. As you know, when water becomes ice it takes up more space. We say it expands. As it expands, the ice makes the cracks in the rock a little deeper. Some day a boulder will break away from the side of the rock. This cracking and splitting also happens to the bricks and stones forming the walls of buildings and their foundations. Check the walls or foundations of your home for signs of this cracking.

Elsewhere water does its work in other ways. Ocean waves beat upon the shore and break away rocks and soil. Cliffs facing the ocean may in time break off and fall into the sea. Rivers carry away the soil. The Mississippi River, for example, steals 730 million tons of soil yearly from the fertile Midwest and deposits most of it in the Gulf of Mexico.

Building Up the Land

When soil is carried away by a river, it is deposited near the river's mouth. This fine soil spreads out in a fan-shaped area called a *delta*. The delta of the Mississippi in the Gulf of Mexico is made of fine, fertile soil. The delta of the Nile River in Egypt extends out into the sea 200 miles.

The Rhine River of Germany and Holland has built a fertile delta on which fine crops grow. In short, while rivers carry away soil from one part of the land, they place it in another part.

We see that, as land is worn down in one place, it is built up in another. Thus rains wash the soil of hills and mountains into the valleys. Rivers wear away the sides of canyons and bring the rock and soil to the lower reaches of the river or to deltas.

Weathering and erosion do their work slowly. They cause many tons of soil and rock to be moved to new places. In the places where these deposits are left, pressure increases. This pressure in the course of millions of years may push higher the parts of the land from which the soil and the rocks were removed. Thus the land is uplifted in one place and lowered in another.

You will get an idea of how this happens if you squeeze some bread dough or clay with your fingers. You may think of the pressure of your finger as the pressure of billions upon billions of tons of soil. Notice that, as you press down on one part of the dough, another part pushes up. Of course the earth is not soft like dough, but this is a good way to see how downward pressure in one place can cause uplifting in another. Also you must remember that what you can do in a second with dough takes millions upon millions of years in the earth.

The building up of the land is also done by earthquakes and volcanoes. Although these forces may destroy man and the things he builds, they also may build mountains. For instance, cone-shaped mountains, often with craters in the tops, are built up by the action of volcanoes (Fig. 73). During a volcanic eruption, large amounts of rock and lava are thrown up into the air. They fall around the volcano and may build it up into a mountain. Mount Rainier in Washington and Lassen Peak in California were once volcanoes. (Mt. Lassen is still listed as active.)

Now perhaps you see more clearly that, while the land is being worn away in one place, it must be built up elsewhere. We cannot really lose any of the stuff of which the earth is made. Every soil particle, every rock, is chained by gravity to this earth.

The Force of Gravity

As you look at a globe representing the earth, you may wonder what keeps the rocks, the air, and the oceans in place. Why don't the loose rocks fall off the earth and out into space? Why don't you yourself fall off the earth? If you were standing at the North Pole and another person were at the South Pole, would not one of you fall off the earth? Only one of you would be standing "on top." Part of the answer is that there is no top or bottom to this earth. Every one of us, everything — rocks, buildings, oceans — all are held to this earth by the force of *gravity.*

The Great Pull of Gravity

About three hundred years ago, Sir Isaac Newton found an answer to the questions about why things do not fall off the earth. This British scientist was the first to give a scientific reason for why things have weight. He said that *every object in the whole universe*

CHARLES PHELPS CUSHING

73 Crater Lake, Oregon, formed thousands of years ago in the broken cone of Mount Mazama, which was once an active volcano. Wizard Island is the cone of another inactive volcano which grew inside the old mountain. Volcanoes are mountain builders.

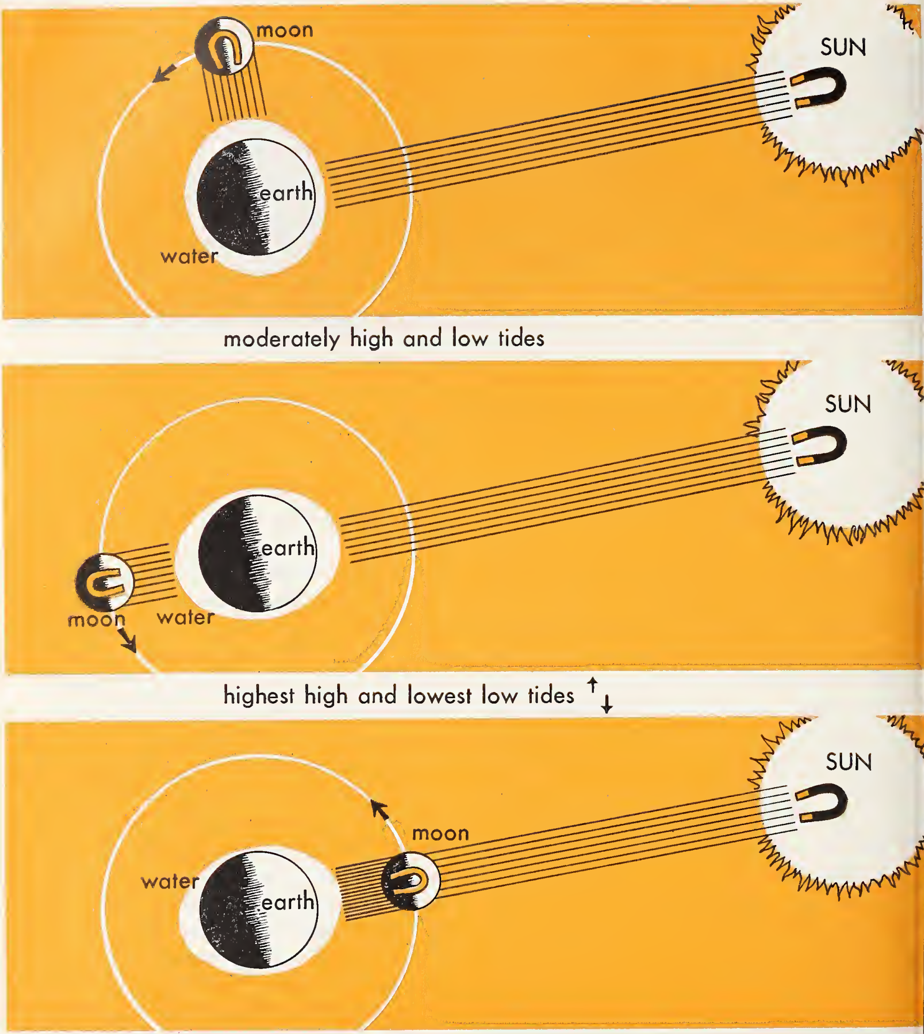
pulls on every other object. He called this the Law of Universal Gravitation.

Of course, masses that are very far away from each other have very little pull on each other, even though they may be as big as our sun. But the sun has a strong enough pull to hold the earth in its orbit. And the earth has a strong enough pull to hold the moon in its orbit. We call this strong pull an attraction of one mass for another. And if the earth can hold the moon in place, it is easy to see that it can also hold on to small masses like rocks and people. The ocean and the atmosphere are also held in place by the force of gravity.

When you weigh yourself, you are measuring the amount of this attraction between yourself and the earth. Your total weight is the total force with which the earth pulls on you. Where is this force located? Scientists say the earth attracts objects as if the force of gravity were to be found at the center of the earth. The farther you are away from the center of the earth, the less is your weight. The earth is somewhat flatter at the poles than at the equator. Therefore, a person at either the North or South Pole is nearer the center of the earth than a person at the equator. Consequently a person at the North or South Pole weighs more there than he would at the equator. But unless he were a scientist checking on this fact, the difference would hardly matter, for an explorer at either pole would have far more important matters to concern him.

Explorers of the moon would have a real interest in their weight. On the moon a person would weigh just about one-sixth of his weight on the earth. The moon, being a much smaller mass than the earth, attracts things to it with less force of gravity. On the other hand, an explorer on Jupiter would weigh much more than on the earth. Jupiter is a planet many times larger than the earth. A person weighing 100 pounds on the earth would weigh 264 pounds on Jupiter. But note that his mass would be the same. How much would you weigh if you were on Jupiter?

You do not need to leave the earth to notice the effects of the attraction of other heavenly bodies upon the earth. All you have to do is watch the rise and fall of the tides.



74 The highest high tides and the lowest low tides take place when the sun and moon combine their pull upon the earth and its waters. At other times the tides are not so high or so low because the effects of the two pulls more or less balance each other.

The Tides

You know now that both the sun and the moon exert a pull upon the earth. But you may be surprised to learn that the moon has a greater effect on the tides than the sun has. This is so because the moon (although so much smaller than the sun) is much nearer to the earth. The sun, being 370 times as far away as the moon, has a smaller attraction for the earth in spite of its greater size. The pull of gravity depends not only

upon the amount of material (mass) of the bodies but also upon the distance between them.

The pull of the sun and the moon on the earth has hardly any effect that you can notice on dry land. However, the water of the oceans can move much more freely, and the pull of the sun and the moon causes a regular change in water level that is easy to see. These changes in level of the oceans and of the water in harbors are called the tides. If you have ever visited a place on or near the seashore, you know that the water rises for about six hours and then falls away for about six hours twice each day. When the tide is out (low) along our Atlantic seacoast, it is also out along some other coast halfway around the world. One-quarter of the way around the world in either direction you would find high tides at the same moment. The diagram in Fig. 74 helps make this clear.

Tides are important to anyone who goes to sea in a ship, whether it is an ocean liner or a rowboat. Every once in a while you hear of some unlucky person who has been swept away by tidal currents. Usually it is because this person did not know about them or did not know how strong the currents were. Never risk your life in tidewater unless you are sure you are strong enough to swim or row or paddle back to shore against the current. For safety's sake always swim where there are lifeguards and stay within the area they are watching.

Large ocean liners can enter and leave certain harbors only at high tide. Shell fishermen work along the shore harvesting clams and oysters when the tide is low. Tides also help to keep our harbors clean, but they often litter our bathing beaches with debris from ships and broken piers, and with garbage thrown overboard far out at sea.

The greatest difference in water level between high and low tide occurs at *spring tide;* the least at *neap tide.* These special tides are caused by the changing positions of the moon and the sun in relation to the earth. These changes take place every month, and so the name spring tide is a poor one. We have spring tides twice monthly, not just in the springtime. It may help you to understand these special tides better if you look at figures such as those in the table, showing the tide levels at a place where great changes take place between high tide and low tide.

TABLE 4 Tide Levels

Tide	*High-Water Mark (in feet)*	*Low-Water Mark (in feet)*	*Difference (in feet)*
Normal	34	8	26
Neap	27	12	15
Spring	42	5	37

When the moon is new or full, it is most nearly on a straight line with the earth and sun. Both moon and sun exert a pull. Study Fig. 74 carefully. You will be able to see why the highest and lowest tides happen when the sun, earth, and moon are in line. You will begin to see how the forces of gravity of the sun and the moon are working together to make our spring tides.

Picture the moon at the first or third quarter position. Now the moon's pull is responsible for a medium high tide in spite of the pull of the sun in another direction. This

medium tide is a neap tide. Can you see from Fig. 74 why these neap tides are not as high or as low as those which take place when the sun and moon are pulling together?

It would be interesting to study the tide table for some seacoast city and see if you can find a relationship between the kind of tide and the phases of the moon. Both facts are given in some almanacs. All you have to do is to find and compare them.

Would You Leave Home?

You see that this earth — our home — is a planet in space under the control of great forces like gravity.

Is man forever to be chained to the earth by gravity? Will he ever be able to visit other planets? In short, can he go out into space? Can he visit the moon, only a short 240,000 miles away? Let us look at the moon and see.

OUR MOON

About ninety years ago the Frenchman, Jules Verne, wrote his famous story, *From the Earth to the Moon*. Ever since, the idea of visiting the moon has had great appeal. Many people have put their names on a waiting list (see p. 185) to be passengers aboard the first rocket ships to make the trip. Even though a rocket was sent beyond the moon early in 1959, these would-be space travelers may have quite a long wait, but the trip now seems possible. Still it is interesting to think about the moon. What sort of heavenly body is this nearest neighbor in the sky? What might we find on a trip to the moon?

Looking at the Moon

Your target for tonight is the moon. It is an excellent object to watch whenever it is in the sky. Because it is so near, it seems as big as the sun, but it is only 2,160 miles in diameter. That is about one-quarter of the earth's diameter. The moon is close to the earth — only about 240,000 miles away on the average, or about ten times as far as the distance around the earth at the equator. An accurate aim and the right timing are needed to send a rocket to the moon.

The scientist who aims a rocket at the moon has to figure the path of the rocket and also the path of the moon. Both will be moving rapidly through space during the time the rocket is in flight. The path of the moon is known. Astronomers have known for many years how to figure its exact position in the sky.

You will probably be surprised to find out how much the position of the moon changes from night to night. To find out, watch the moon every night for a month. Of course, you will not be able to see the moon every night, but watch several nights in a row. Be sure you observe it at the same time on each of these nights, say 9 P.M. Where does the moon rise? Where does it set?

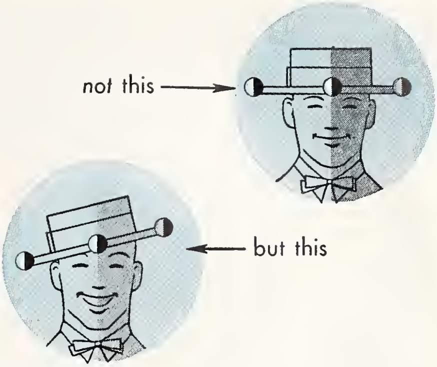
During a single night you will see the moon rise in the east and set in the west. Notice that it rises and sets about 51 minutes later each night than the night before.

The Journey of the Moon

To "see" how the moon is really traveling around the earth, you will need to do a simple stunt. For this

you will need a hat with a brim that can be tilted so that it will encircle the crown at an angle of about 5 degrees (Fig. 75). If you think of the crown as the earth, the circle made by the brim is the moon's orbit. As you remember, an orbit is the path an object in the sky takes around another object. The moon's orbit is its path around the earth.

Hold a ball at the edge of the hat brim and at your eye level, as in Fig. 75. If you move the ball all the way around the brim and back to its starting point, you have a good example of the way the moon travels on its orbit.



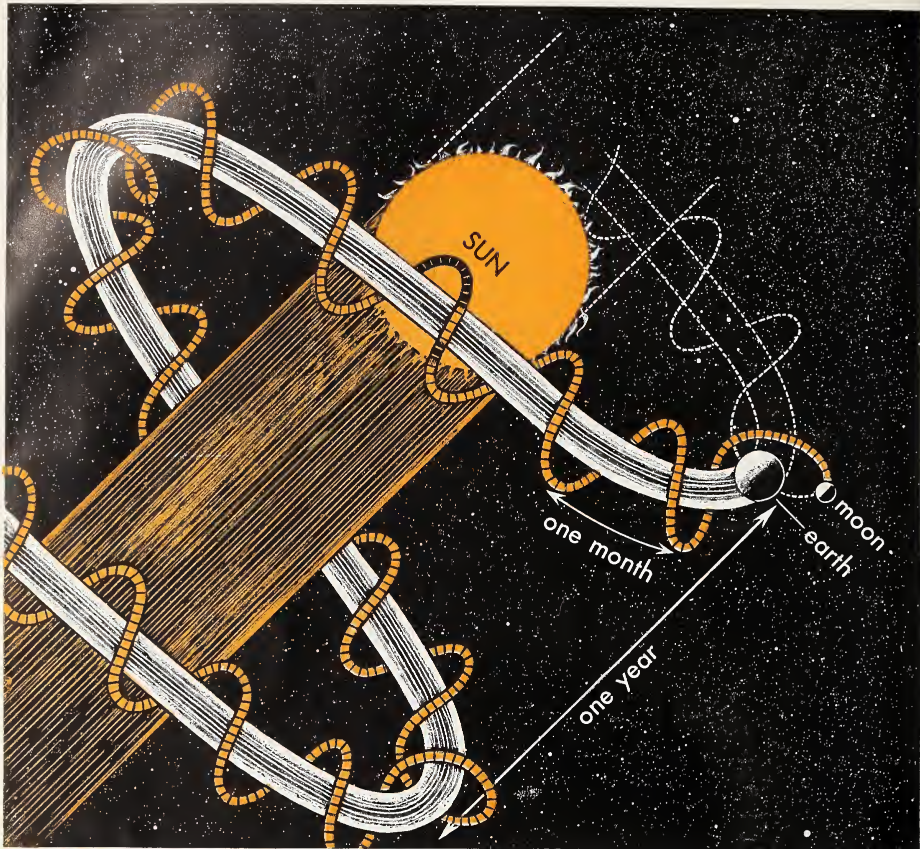
75 The orbit of the moon around the earth is tilted at an angle of about 5 degrees. This is enough to reduce the number of total eclipses and to cause important differences in the way the moon appears to us. Try it. Cut out a hat like the one shown, and explain how the tilt of the moon's orbit reduces the number of total eclipses.

The time for the moon's entire trip is 29½ days, or about a month. In ancient times, this period of time was named for the moon and called a "monath." From this we got our word *month.* This kind of month is easy to keep track of even without a calendar because the appearance of the moon changes completely every 29½ days. These changes in appearance are known as the *phases* of the moon.

The Changing Phases of the Moon

The size and shape of the moon's face seem to us to change from night to night. To understand this we will have to look at the sun, the earth, and the moon from the point of view of an observer in space. Look at Fig. 76. It shows how each of these bodies is moving. The sun takes the earth and moon along with it and sheds its light on both. Half the earth and half the moon are lighted by the sun. The other sides of each are in the dark. If you follow the path of the moon, you will see that twice during a month the moon is nearly in line with the sun and the earth. At two other times the moon is at right angles to a line between the earth and the sun. The position of these three bodies at intervals of about 3½ days is shown in Fig. 77. The earth and moon always are half-lighted, half-dark, but to a person on earth the size of the lighted area on the moon seems to change. These are the moon's phases.

To see how the moon's phases change, do this simple stunt. Turn on a bright light in an otherwise dark room. It is best to have no shade on the lamp. Now hold a tennis ball at arm's length. Turn slowly on your heel. If the lamp is bright enough, the ball may become almost invisible when you hold it between your eyes and the lamp. This is like phase 1 in Fig. 77, the *new moon* phase. The



76 This diagram (not drawn to scale) shows the motions of the sun, the earth, and the moon. Yes, the sun moves through space. As it does so, it pulls with it the earth, which revolves around it. The moon also moves, revolving around the earth.

side of the moon and of the ball turned toward us is dark at this phase. For this reason the new moon is often called "the dark of the moon." For a day or two we may be unable to see it, since the lighted side is turned away from us.

The next phase is shown as phase 2 in Fig. 77. The moon is shaped like a thin crescent. The cusps or "horns" of the crescent moon are turned away from the sun. This phase is never seen near midnight, but it may be seen before sunset. Often after dark at this phase the whole outline of the moon may be seen dimly lighted (by earthshine). Earthshine is sunlight reflected by the lighted half of the earth. This earthshine lights up the moon just as moonlight does the earth. You may hear people refer to this effect as the "old moon in the new moon's arms."

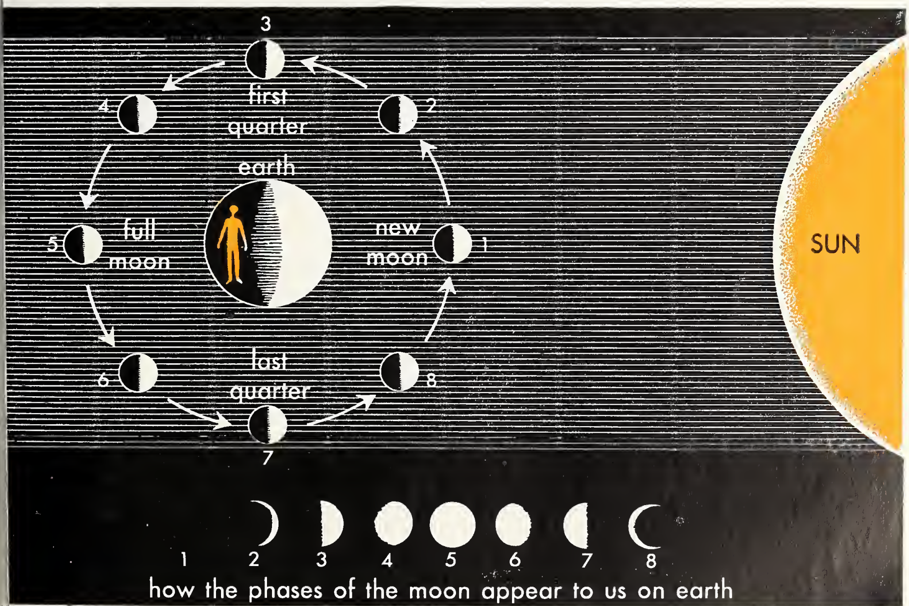
As the days go by, the entire face or disk of the moon becomes strongly lighted. When the moon is on the far side away from the sun, the sun's rays light up the side of the moon facing us. This is the beautiful *full moon* phase.

After the full moon, the line separating the dark half of the moon from the sunlit half slowly moves across the moon's surface. The size of the lighted area seems to wane (grow smaller). The shape once more becomes a crescent. As the moon revolves around the earth, therefore, it reflects in our direction different amounts of light from the sun. If you were to study photographs of the moon taken during one month, you would notice that they all showed one side. True, we see different amounts of the moon's surface during a month, but it is always the same surface. No one has ever seen the opposite side of the moon. How can this be?

The explanation is that as the moon revolves about the earth it is also rotating on its axis in the same period of time. Thus it always presents the same side toward us. Actually, because of the tilt of the moon's orbit and its slight wobbling, we can see at one time or another about 59% of the moon's surface. No one really knows what is on the other 41%.

It is not difficult to show how we happen to see just one side of the moon. Place a chair in the center of the room. Imagine it to be the earth. You will be the moon. Face

77 The reason the moon goes through phases may be understood by studying this diagram. At new moon the lighted half of the moon is on the side away from an observer on the earth. At full moon, we see the entire lighted half. How much do we see at first quarter? Why is it that the other side of the moon is not seen?



the chair. Continue to face it all the time while you walk completely around the chair. Notice that you have actually faced all four walls of the room during your trip. Facing all four walls is the same as rotating once. You, therefore, rotated once while you revolved once around the chair. The moon takes 29½ days to make one revolution around the earth.

One of the aims of the first moon explorers will be to get pictures of the unknown surface that no one has ever seen. Before this, we may get them by television from a satellite sent into orbit around the moon.

ON THE MOON

Any rocket that is built to take a crew of explorers to the moon will have to be able to withstand a rough landing.

It will be useless to come down by parachute, for there is very little or no air above the moon's surface to support it. At least there will be no danger of the rocket's falling into an ocean on the moon. There is good evidence that there are no oceans there because there is no water. This is something you must have in mind before you look at a map of the moon's surface. Otherwise the names you see on the map may fool you. The astronomers who first looked at the moon through low-power telescopes thought the large, dark areas were bodies of water like the oceans on the earth. They gave these areas names such as the Sea of Showers and the Ocean of Tempests. On the moon you will probably not find any seas nor showers nor oceans nor tempests. What, then, would you find?

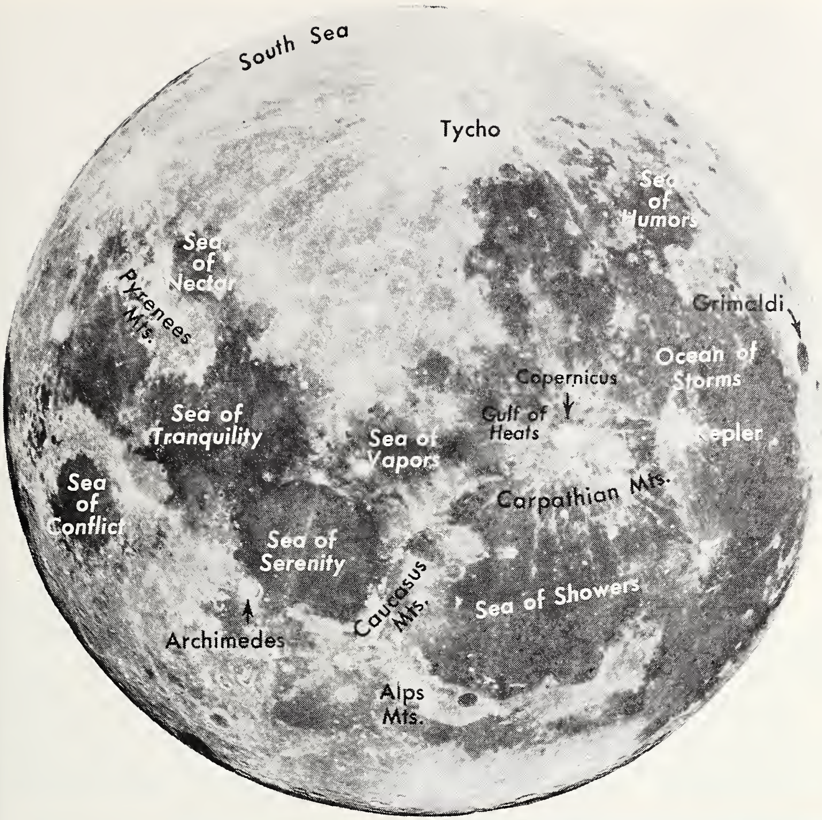
The Moon's Landscape

The mountains on the moon are unlike any on the earth. The mountains of the earth all show the effects of weathering, that is, changes caused by wind and rain, heat and cold. There is no weather on the moon. Therefore the mountains are rough and the stones sharp. There is no soil like ours on the moon, but there may be a thick layer of ashes from dead volcanoes.

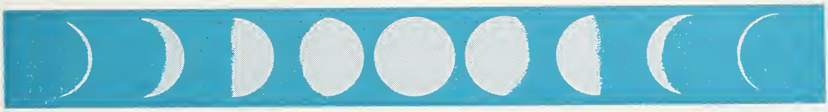
There is no sign of volcanoes now active on the moon, but there are many craters. Some people think these may have been active volcanoes at one time. From the earth these great, round holes on the moon certainly look like the kind of craters made by volcanoes (Fig. 79).

The only other way to explain these craters is to say that they were made by great pieces of rock that fell onto the moon from somewhere in space. These craters range in size from small ones, one-tenth of a mile in diameter, to giants that are hundreds of miles across. Some craters on the moon have high mountains inside them. Others have smaller craters within their walls. These craters have been named for famous astronomers, for example, Copernicus and Kepler.

Besides mountains, plains, and craters, the moon's surface is also marked by rills and rays. The rills are narrow, deep trenches which are 10 to 300 miles long and about 2 miles wide. No one knows how deep they are. The markings called rays are even more of a mystery. They cast no shadows. Therefore, they are neither high nor low; that is, they are neither ridges nor rills. They seem to spread out in all directions from some of the



AMERICAN MUSEUM OF NATURAL HISTORY



78 *Top*, the landscape of the moon is a map of craters, plains, and mountains. *Bottom*, the phases of the moon begin with new moon. We cannot see the new moon (except during an eclipse of the sun) because only its dark side is toward us. A few days later we see the new crescent moon, and then in about two weeks we see the full moon.

craters. Explorers to the moon will certainly want to find out what the rays are and what made them.

Men on the Moon

Of late a great deal has been written by men of science about the way the moon will be visited and explored. If the moon is not explored within your lifetime, it won't be for lack of trying. The main trouble is that people are not sure that men can live through a trip to the moon even if rockets can be built to take them there. The dangers are real enough. On this point all agree.

79 A view of the sky from the moon shows the sun and the earth as a crescent shape. Note the rugged landscape of the moon's surface. Since the moon has no atmosphere, the sky would appear black even in the daytime, and the stars would be clearly seen.

Because the moon has very little or no air, men will not be able to stay alive unless they carry their own air supply in tanks on their backs. Our explorer will need an airtight suit to keep the air pressure on his body about the same as it is on the earth. This suit will have another use. It will protect him from the burning rays of the sun. Temperatures on the moon range from 214° F. by day to −243° F. at night.

On the moon there will be other strange things. A man on the moon will weigh about one-sixth as much as on the earth. He will hear no

sounds except those he can make inside his space suit. He will have to talk to his crewmates by radio. He will have no water to drink unless he brings it with him, and then he must find a way to get it into his mouth. His food will have to be pre-cooked or raw because he will have no fire.

In answer to these problems, air-tight living quarters will have to be built as fast as possible. Once inside a hut that has indoor conditions like those on the earth, an explorer could take off his space suit, eat, rest, and work. The plan is not impossible, but that it can be done by men in space suits remains to be seen. The United States Army, Navy, and Air Force are now at work testing men and materials to see whether it is possible to stay alive under space conditions. Until the day that man can safely explore the moon, we can go on learning more about it by watching it as it travels around us.

ECLIPSES BY AND OF THE MOON

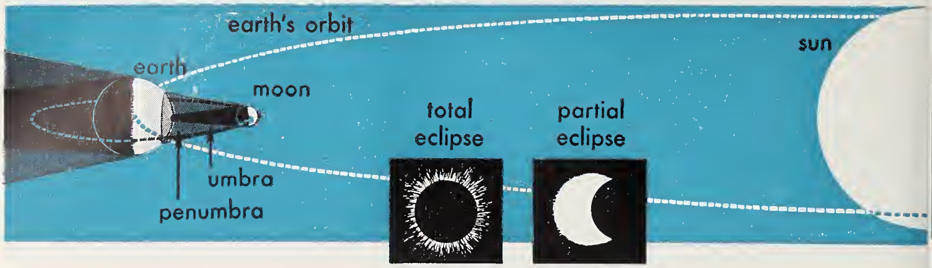
One of the strange things a man on the moon would see would be a black sky in which the stars would be visible even in the daytime (Fig. 79). This would be possible because there is no air on the moon. If there is no air, there is no airborne dust which on the earth scatters the sun's light. This scattered light gives us a blue daytime sky which acts like a screen, hiding the stars from our view.

Dimouts and Blackouts

Strangely enough, because of the moon, there are times when even on the earth you can see the stars in the daytime. This happens seldom — only during a total *eclipse* of the sun. An eclipse of the sun takes place when the moon travels between the sun and the earth in just the right way. This does not happen very often.

According to one astronomer, a total eclipse of the sun was seen only twice in London and only three times in Rome in the 1,200 years between 600 A.D. and 1800 A.D. In a total eclipse, the moon is directly between the earth and the sun so that the moon's shadow falls upon the earth (Fig. 80). The most recent total eclipse seen clearly in the United States was in 1932. One was also seen in northern cities about dawn on June 30, 1954. The next one in the United States was to occur at sunrise in New England on October 2, 1959, not a very good time for viewing an eclipse because of the low position of the sun in the sky. The next good total eclipse of the sun will be seen in the United States on July 20, 1963. It will last only one and a half minutes. The people who will see this eclipse will have to be in New England. At that time newspapers will have maps to show just where the eclipse will be seen. Even so, do not count on seeing it, for clouds may hide the whole show. In that case, only those in airplanes above the clouds will be able to see it.

Suppose, however, that it is a bright and clear summer day. Then, if you are looking at the sun through a pair of heavily smoked glasses such as welders wear, you will note a dark object moving in along the western edge of the sun's disk. This is the moon moving rapidly. Within a half hour, the light will fade from the sky, as it does when a swift thunderstorm approaches. The sky



80 Partial and total eclipses of the sun occur when the moon is at a place in its orbit that allows its shadows to fall on a bit of the earth's surface. Viewers within the moon's penumbra see a partial eclipse. Those within the moon's umbra see a total eclipse of the sun.

will darken rapidly. Soon the sun will be completely hidden. The stars will come out. Tiny sparks of light will shine around the edge of the moon. These are known as Bailey's Beads. They are caused by the light of the sun shining through the valleys and rough places on the moon's surface. Then you will see a beautiful glow like a halo surround the dark disk of the moon. This halo is the sun's *corona* (Fig. 84). It is one of the most wonderful sights in nature.

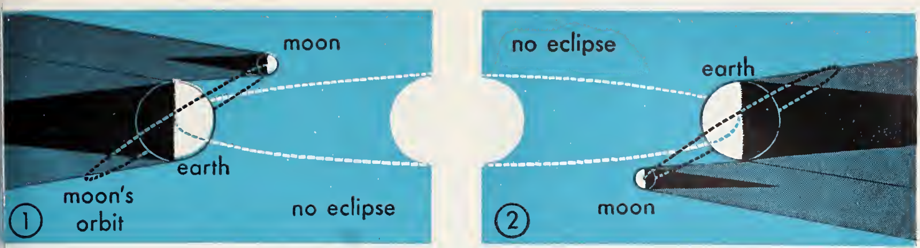
At the same time you may see tiny tongues of light which look like flames. These are called *prominences*, and they are not tiny. The largest measured have reached 1,056,000 miles beyond the sun's surface. Some may extend far beyond this.

The moment of the total eclipse soon passes. It is never more than about 7½ minutes. In 1963 the time will be 1½ minutes. At the end of this time, the corona will disappear. Soon the blackout of the sun will become a dimout again. In a little while the eclipse will end. As you watch, the shadow of the moon will leave the earth and become lost in space (Fig. 84).

Another Eclipse

To see a total eclipse of the sun you have to be standing on the part of the earth touched by the *dark part* of the moon's shadow. This is called the *umbra* (UM-bruh). Notice in Fig. 80, however, that there is a light part of the shadow as well as a dark part. Should you be standing on a portion of the earth touched by the light part of the shadow, you would not see a

81 An eclipse of the moon takes place when the moon travels into the earth's shadow. In the earth's penumbra the moon is partially eclipsed, but in the earth's umbra the moon's eclipse is total.



82 Because of the tilt of the moon's orbit (see Fig. 75), the moon's shadow may fall (1) above the earth's surface or (2) below it. When this happens no eclipse will take place, even though the moon is between the sun and the earth.

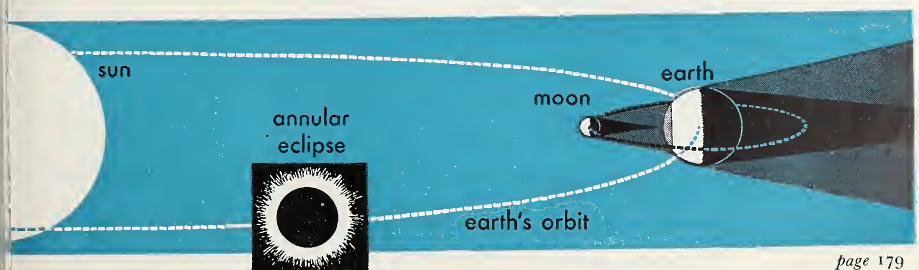
total eclipse. You would see only a partial eclipse. This partial eclipse may be seen in the portions of the earth on either side of the dark path of the moon's shadow, the umbra. The lighter part of the shadow is called the *penumbra* (peh-NUM-bruh).

Perhaps you had not realized that there are light and dark shadows. It will not be necessary for you to wait for another solar eclipse to find out what they are. Just clench your fist. Hold it about four or five inches above a piece of white paper that is about two feet below a bright light bulb. See the two shadows on the paper. The darker one, the umbra, is inside. What is the outer, lighter shadow called?

The earth itself also casts an umbra and a penumbra into space from the side turned away from the sun. At times the moon travels into these shadows (Fig. 81). When the moon is in the penumbra of the earth's shadow, we see a partial eclipse of the moon. When the umbra of the earth's shadow covers the moon, we see a total eclipse of the moon. This is called a *lunar eclipse. Lunar* comes from the Latin word for moon.

You might reasonably suppose that there would be two eclipses a month. You might expect an eclipse of the sun at new moon, when the moon is between the earth and the sun. You might expect a lunar eclipse at full moon, when the earth is between the moon and the sun (Fig. 82). But this does not happen. There are several reasons why conditions for an eclipse of the moon or the sun are right only a few times each year. It is

83 An annular (ring) eclipse of the sun is seen when the moon is so near the sun that its umbra is not long enough to reach the earth. Then the moon appears too small to hide the whole sun.



HAYDEN PLANETARIUM, AMERICAN MUSEUM OF NATURAL HISTORY

84 *Top*, the sun's crown of light (its corona) is a glorious sight during the few moments of a total eclipse of the sun. *Bottom*, an eclipse of the sun begins (far right) and becomes total as the moon covers more and more of the sun's surface. Did you see the last eclipse on June 30, 1954?

as though the earth and the moon were playing shadow tag.

Shadow Tag

Have you ever played shadow tag under a street light? Those who play this game usually seem to be having a great deal of fun. The idea is to tag the other fellow with your shadow rather than with your hand. There is a trick to it. First, you have to be between the person and the light. Second, you have to be far enough away from the light and yet near enough to the one you want to tag so that your shadow will be long enough to reach him. The farther you get away from the light, the longer your shadow will be. You may also avoid being tagged by getting above the level of the person who is "it."

If you think of the earth and the moon as playing shadow tag, you will be able to understand why total eclipses happen so seldom. First, the earth, the moon, and the sun are nearly in a straight line only twice a month—at new moon and at full moon (Fig. 77).

In the second place, remember that the moon's orbit is tilted (Fig. 75), so the moon may be a bit above or below the earth at these two phases of the moon. If this happens the moon's shadow passes over or under rather than across the earth (Fig. 82). These bodies are in space and are seldom at the same level at the times when they are in line with each other and the sun.

In the third place, the earth and the moon travel in orbits that are not true circles (Fig. 86). Sometimes when the moon is too near the sun, its shadow is not long enough to tag the earth. Then the moon does not cause a total eclipse of the sun. Instead of a total eclipse of the sun we have an *annular* (AN-yoo-ler) eclipse (Fig. 83). In an annular eclipse the disk of the moon is too small to cover the sun. A ring (or *annulus* in Latin) of the sun shines out from around the black disk of the moon. During this kind of eclipse, the sky darkens no more than it would if a dark cloud were to come between us and the sun.

Thinking it over, you will see how hard it is to have all the conditions needed for an eclipse. The sun, moon, and earth must be exactly in line,

and the shadow must be long enough. Eclipses of the sun can be seen only by people who happen to be on the small part of the earth touched by the moon's shadows. Because eclipses of the moon can be seen anywhere on the side of the earth that is darkened, they are seen by more people. Some light from the sun is bent around the earth by the earth's atmosphere. Therefore, during a lunar eclipse the moon never disappears. It just becomes a dark copper color. You can watch a lunar eclipse as safely as you can look at the moon itself with no protection for your eyes. Always remember, however, not to look at the sun even during an eclipse without protecting your eyes with welders' dark glasses or a darkly overexposed piece of film from which photographs are made. Ordinary sunglasses will not protect your eyes from direct sunlight.

The Moon — An Uninviting Satellite

Now you have some ideas about the moon, how it takes part in an eclipse, and what it would be like to pay it a visit. It is fascinating to see a motion picture of its surface or to watch its eclipses. In time a well-aimed rocket will land on the moon or go into orbit around it.

Experiments now going on may give us a rocket with enough power to make a landing. To do this the rocket, after leaving the earth, must reach a speed of nearly 25,000 miles per hour. By 1959, rocket builders had made rockets that had reached this great speed. You will read about them in the next chapter, which tells the story of space exploration as far as it had gone by 1959.

For the present you will have to be satisfied with looking at the moon through a telescope. If you have never done so, you have missed an exciting adventure. If someone owns a telescope in your neighborhood, he may let you look through it at the next full moon. An even better idea is to make your own telescope. If you can't get a telescope, use a pair of strong field glasses (binoculars) to study the surface of the moon. You will see an uninviting land which men will some day explore, or die trying. What do you think are their chances of success?

MOUNT WILSON AND PALOMAR OBSERVATORIES

5 If you decide to go
to astronomy as a
reer, you may some
ay use a powerful tele-
ope and see the "horse-
ead" nebula in the con-
ellation of Orion. It is
cloud of solid material
ding the sky behind it.
s silver lining may be
ght from a bright star
back of it.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

annular eclipse	umbra	fault
corona	penumbra	weathering and erosion
phases of the moon	lunar eclipse	gravity
total eclipse	partial eclipse	spring tides
prominences	seismograph	neap tides

1. the highest high tides and the lowest low tides
2. an extremely sensitive instrument used to detect earthquakes
3. the gradual destruction of things exposed to wind, rain, and changes of temperature
4. the force that holds everything to the earth
5. a bright white light which surrounds the moon for a few seconds when the sun is totally eclipsed by the moon
6. the lighter part of a shadow
7. an eclipse of the sun in which a ring of the sun appears around the black disk of the moon
8. flamelike tongues of light that appear to rise from the surface of the sun while it is being eclipsed by the moon
9. changes in the appearance of the moon which repeat every 29½ days
10. the darker part of a shadow
11. the complete hiding of one heavenly body by another
12. when the earth is between the moon and the sun
13. the incomplete hiding or darkening of one heavenly body by another
14. tides during which there is very little change in the level of the water between high tide and low tide
15. a long crack in rock, on one side of which masses of rock have slipped downward

Test Yourself

In your notebook, complete the following sentences with a correct word or phrase. DO NOT MARK THIS BOOK.

1. You are standing at the bottom of an ocean of . . . .
2. . . . show that the interior of the earth is still very hot. Earthquakes usually occur where there are . . . in the earth. To locate an earthquake from a distant point, scientists use an instrument called a . . . .
3. One of the major forces causing changes in the earth is gravity, the laws of which were first stated by . . . . This force accounts for the . . . on the earth which are caused by the pull of the sun and the . . . .
4. The moon is our nearest sky neighbor, being only . . . miles away from the earth.

5. The moon is only . . . miles in diameter.

6. The moon travels around the earth once every . . . days and goes through a complete change of phase in . . . days.

7. Only about . . . % of the moon's surface has been seen by man.

8. The moon appears to rise in the . . . and each night it rises about . . . minutes later than it did on the previous night.

9. We cannot see the moon when it is exactly at the . . . phase except when it is causing an eclipse of the sun.

10. We see the moon because it . . . light from the sun.

11. The chief cause of earthquakes is the . . . of rocks where there is a . . . .

12. Ocean harbors have . . . because of the pull of the sun and the moon.

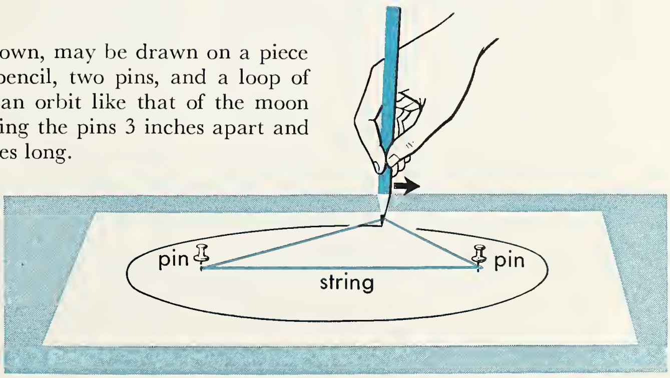
GOING FURTHER

In the Laboratory and Field

1. *Testing gravity.* Find two things of the same size but of different weights. You can take two blocks of wood of the same size and in one of them drill a hole, and fill the hole with lead. Now carry both blocks to the top of a stepladder and roll them both off a board at the same time. Observe whether one hits the ground before the other, or whether they both hit the ground at the same time. What do you conclude? Repeat this experiment with other objects and with the same objects dropped from different heights. Give a full report on your observations.

2. *The moon's orbit.* Make a model showing the relation of the moon and its orbit to the earth. Use it to explain why we do not have eclipses more often. You can draw the shape of the moon's orbit on paper by holding your pencil as in Fig. 86.

3. *Sizing up the moon.* Although the moon is only 2,160 miles in diameter and the sun is about 864,000 miles in diameter, the moon seems to be about the same size as the sun as we see them in the sky. To understand how a small object can hide a larger one, hold a penny close to your eye. See how it completely hides much bigger objects across the room.



86 An ellipse, as shown, may be drawn on a piece of paper by using a pencil, two pins, and a loop of string. The shape of an orbit like that of the moon can be drawn by setting the pins 3 inches apart and using a loop $5\frac{1}{2}$ inches long.

Put on Your Thinking Cap

1. Why are the forces of weathering and erosion able to cause greater total destruction than earthquakes and volcanoes?
2. Give your opinion of the statement, "Nothing is changeless except change."
3. The diameter of the moon is only one-quarter the diameter of the earth. How then is it possible for the moon to eclipse the sun, whose diameter is more than a hundred times that of the earth?
4. Why will it be difficult to send a crew of men to explore the moon?
5. Why is the expression "an elastic shadow" a good one to use to describe the moon's shadow?

Adding to Your Library

1. *From Earthquake, Fire and Flood* by R. Hewitt, Scribner, 1958.
2. *The World We Live In* by Editorial Staff of LIFE and Lincoln Barnett, Simon and Schuster, 1955. The building of mountains, the tides and waves, the sky, and strange creatures are a few of the many topics described with many colored pictures in this book.
3. *The Story of Caves* by Dorothy Sterling, Doubleday, 1956. This is a simple, interesting book about how caves formed, how to find a cave, and what you can expect to find in a cave.
4. *Exploring Earth and Space* by Margaret O. Hyde, Whittlesey, 1957. The story of the International Geophysical Year (IGY).
5. *Sun, Earth, and Man* by George P. and Eunice S. Bischof, Harcourt, Brace, 1957.
6. *Science in Your Own Back Yard* by Elizabeth K. Cooper, Harcourt, Brace, 1958. All about rocks, stars, exploring on your back, on your stomach.
7. *The Moon* by George Gamow, 2nd edition, Abelard, New York, 1958.
8. *From the Earth to the Moon* by Jules Verne. *The First Men in the Moon* by H. G. Wells. *The Adventures of Hans Pfaall* by Edgar Allan Poe. Read these for fun. You will have to look for these books in the library under "Fiction," for they are not science books but science fiction. Look for errors of fact as you read.

A Bit of Research

You can become an authority on the moon simply by watching it and making notes about its position, phases, and motion. Keep a notebook of facts and observations. You will be surprised how much more there is to learn about the moon than you have learned from the reading of this chapter.

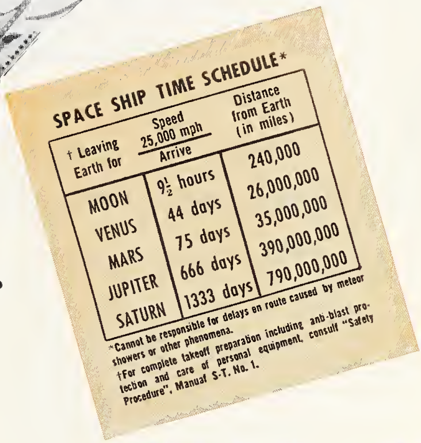
Careers for You

You might also join a "moon-watching" team and watch for satellites. You can volunteer for a couple of hours of such duty each week, and learn a great deal about astronomy at the same time.

You may also prepare yourself for a career as an *engineer* or *astronomer* who will make history by sending a rocket to the moon.

CHAPTER 9

Space, Our New Frontier



SPACE SHIP TIME SCHEDULE*

† Leaving Earth for	Speed 25,000 mph Arrive	Distance from Earth (in miles)
MOON	9½ hours	240,000
VENUS	44 days	26,000,000
MARS	75 days	35,000,000
JUPITER	666 days	390,000,000
SATURN	1333 days	790,000,000

*Cannot be responsible for delays en route caused by meteor showers or other phenomena.
†For complete takeoff preparation including anti-blast protection and care of personal equipment, consult "Safety Procedure", Manual S-T. No. 1.

Nine and one-half hours to the moon, the space time schedule above tells you. Forty-four days to Venus. Imaginary? Will it happen? Within your own lifetime you may know. The evidence is not yet in.

WOULD YOU LIKE to apply for a trip to the moon? No, we are not joking. Above is an exact copy of a card that was given to people who did apply at the Hayden Planetarium in New York City.

Hundreds of people have signed these cards. Many, no doubt, really hope to go traveling somewhere in space and not merely sit in a planetarium armchair to do it.

If this were a stunt thought up by a fiction magazine, we would not give the trip a second thought. The Hayden Planetarium, however, is a highly respected, scientific organization. These cards were meant to show that some scientists believe space travel may become possible within our lifetime.

The idea has been talked about so much that we shall try in this chapter to give you a better understanding of the problems of space travel. Even if you never set foot inside a space ship, the idea of man's reaching Mars or the moon, by going out into space, is exciting.

The Wish to Fly

Stories from the early Greeks and imaginary accounts through the ages tell of man's desire to fly like birds. Balloons, harnessed eagles, and cannons had been suggested as sources of power. But none of these would do the job.

Then in 1903, after the development of the gasoline engine, the Wright brothers made the first powered airplane flight at Kitty Hawk, N.C. This was the beginning of man's flight through the air. But what of flight beyond the atmosphere?

Professor Robert H. Goddard, in 1920, published a little book called *A Method of Reaching Extreme Altitudes.* This was the pioneer book on the working of rockets. Three years later Professor Hermann Oberth, of Germany, published *The Rocket into Interplanetary Space.* These early books outlined a practical means for space flights. But much research into design and power for high-altitude rockets was needed before success was achieved.

During World War II the Germans developed rocket missiles which they shot at cities in England. After the war, research on rockets and rocket planes progressed rapidly. In 1957 the experimental rocket plane, Bell X-2, reached an unofficial altitude of 126,000 feet (24 miles). A later plane, the X-15 (Fig. 87), has been designed to fly higher than 100 miles at a speed greater than 3,500 miles an hour. Watch your newspapers to learn of current high-altitude flights.

Along with the work on rockets and rocket planes went research on launching a man-made moon, or little *satellite*, into orbit around the earth. If that could be done, as it was in 1957, perhaps a rocket could be fired clear of the earth and moon to move around the sun like a tiny planet. This was done in 1959.

The Lure of Space Travel

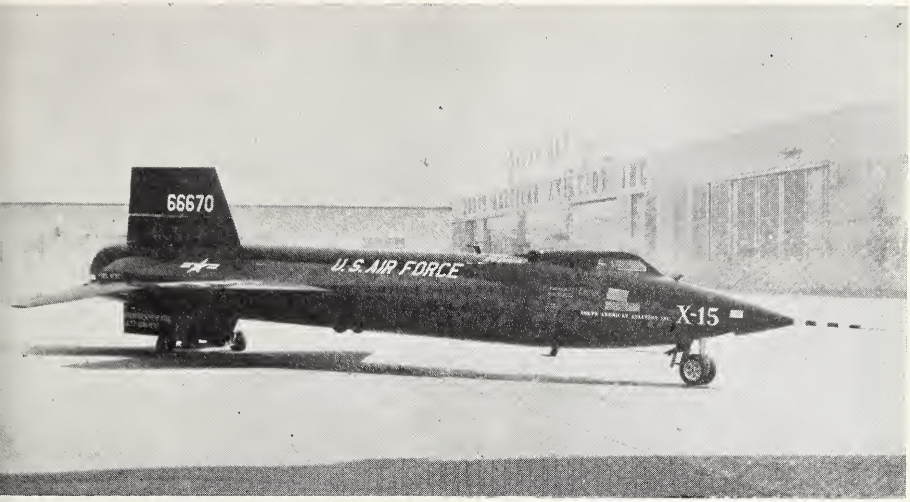
Why would anyone want to go up in a rocket or space ship? Why are we so busy sending up rockets and satellites, each of which costs a very large sum? What is to be learned from this expense?

First, human beings want to know all they can about the universe. Also, they want to go wherever they can and "see for themselves." Since most of the earth's surface has been explored, men want to explore into space.

Second, we as human beings live below a shielding atmosphere. Because many types of light waves are absorbed in the atmosphere, we do not know many things about the other heavenly bodies. We try to reconstruct what conditions are like "out there," but we may be mistaken. Direct observation is the best way to find out.

Third, we need to know more about our home planet, the earth. Surprisingly, our earth-bound conditions prevent us from knowing accurately about the earth's magnetic field, the size and shape of the earth, and the accurate positions of the continents or the nature of the upper atmosphere where weather patterns may begin.

Rockets and satellites developed for scientific purposes can also be used for military ends. While we hope that no one ever fires one as a weapon, the tensions of the times require that we have an arsenal of weapons equal to those of any other nation on the earth.



NORTH AMERICAN AVIATION

This X-15 plane is specially designed for exploring space 100 miles above the earth.

Of these reasons probably the first is the most important. Man has an inexhaustible desire to know as much as he can about everything. But let us start right at the beginning of the story.

The International Geophysical Year

During 1957–58 scientists in 66 countries made special efforts to gather information about the earth and space around us. This period of planned international cooperation was called an *International Geophysical Year*, abbreviated to IGY. Many special studies were carried out, such as the intensive exploration of Antarctica. Part of the work of scientists during this period was to probe into the upper atmosphere and the spaces beyond.

The possibility of getting continuous information for weeks or months from an earth satellite seemed especially important. Automatic detecting equipment for space satellites was designed to gather much information and to relay this to earth by radio.

SATELLITES AND ROCKETS

"Russians Launch Earth Satellite." This headline on October 4, 1957, announced the "Space Age." A satellite, or man-made moon, had been fired some 350 miles beyond the earth and sent flying sideways around it at 5 miles per second. It circled the earth every 96 minutes.

The orbit of Sputnik I, as the Russians called it, was not an exact circle but had an oval shape. Its *apogee*, or greatest distance from the earth, was 560 miles and its *perigee*, or its closest approach to the earth, was 145 miles. At its perigee Sputnik I moved through our very thin upper

atmosphere. By bumping into air molecules, it was gradually slowed down, with the result that its orbit got rounder and smaller. Three months after launching, its orbit was entirely within the thin upper atmosphere. Then it slowed down rapidly, plunged into thicker air and burned up.

This satellite was the first of many to follow. Only a month later, the Russians launched Sputnik II, a larger satellite weighing 1,120 pounds. It carried the first space passenger, a dog named Laika, who lived for more than ten days in a special cabin. This satellite had an average apogee of 600 miles and a perigee as low as 150 miles. There it too met air friction and burned up after five months.

On January 31, 1958, the United States sent up its first satellite, Explorer I. Its weight was small, only 31 pounds, but its apogee was 900 miles. More important, its perigee was 219 miles. As little air remains at that distance, this satellite was expected to stay up for five or more years.

In the first year after Sputnik I was launched seven satellites in all were sent around the earth. Three of these were sent up by the Russians and four by the United States.

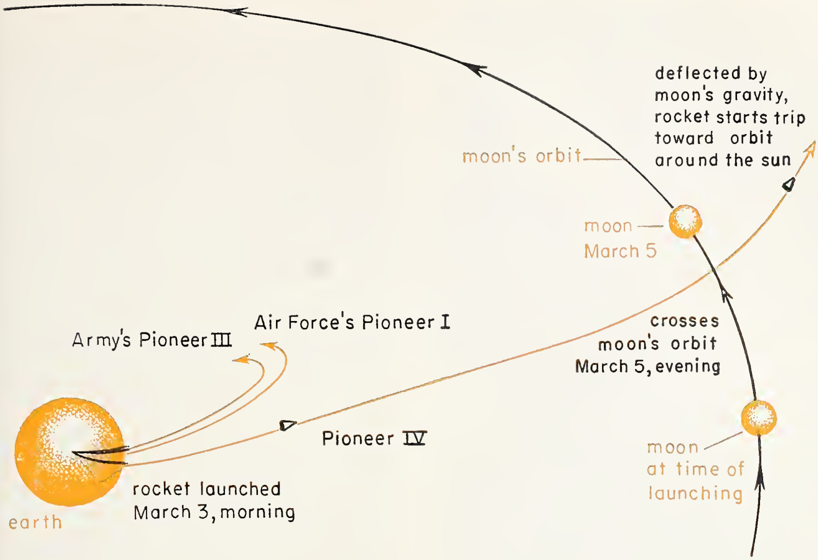
In October 1958, barely a year after the first satellite went around the earth, the United States Air Force fired an 83-pound satellite, Pioneer I, some 72,000 miles into space (Fig. 88). Had it been going just a little faster, it would have gone around the moon and radioed back information about the never-before-seen far side of the moon. To get it up, a three-stage rocket weighing about 88 tons was needed. About one ton of rocket was used for each pound of *pay load.* This rocket went far higher than any previous one. It sent back much important information about conditions far away from the earth.

In January 1959, the Russians fired a rocket ahead of the earth towards the moon near "third quarter." This rocket, named Mechta I, missed the moon and was not much swerved by the moon's pull. It was going so fast that it escaped from the earth's gravitational pull and became the first man-made "planet." Its distance from the sun varies from 92 to 123 million miles and its period around the sun is about 15 months. In March of the same year the United States sent Pioneer IV (Fig. 88) past the moon and into a similar orbit around the sun.

Getting a Satellite Up

To get a satellite up we must send it several hundred miles beyond the earth. Then it must be given a speed of about 5 miles per second sideways around the earth to keep it from falling back to earth.

It may seem strange to you that the speed of a body up and down, in the direction of gravity, has nothing to do with its speed sideways. Yet this was one of the great discoveries that Galileo made three hundred years ago. How high a thrown ball will go and how long it will be up depend only upon its speed straight upward. How far it will go sideways depends upon its speed parallel to the earth and how long it will be before it falls to the ground. That is, we can separate the up-and-down motion from the sideways motion and consider each by itself. This is important



8 Paths of three of the first United States rockets launched to probe space near the moon. Why did Pioneer IV succeed in going into orbit around the sun?

in launching a satellite because we must get it high above the earth and *also send it speeding sideways.*

The powerful first stages of the rocket get it climbing upward and headed in the right direction as Fig. 89 indicates. When at the proper height and moving sideways, a small final rocket adds the needed speed to put it "in orbit." The exact path best for a particular rocket is carefully computed from the size and power of the several rocket stages to be fired. If the rocket is pointed up too much, it loops out to a distant apogee but may run into the atmosphere at its perigee as it falls back along an oval orbit. If it is pointed down too much, it may be trapped in the atmosphere before it makes even one trip around the earth.

Our satellite, Vanguard I, fired in March 1958, goes out 2,466 miles and still misses the earth by 405 miles. In this orbit it may stay up for as long as 200 years.

How Can We Track a Satellite?

Just to get a satellite up but not know where it is or how it is moving is not of much value. Observations can be made in three ways: by radio and radar, by photography, and by just plain looking.

Radio signals, powered by chemical batteries, can be sent from a satellite on very short wave lengths in the many-megacycle bands. These signals can be sent for several weeks before the batteries go dead; if "solar batteries" are used, the signals can be heard for a longer time. Observers can hear the signals only when the satellite is in the sky over the receiver. From 500 miles up, signals sent out can be received over an area larger than the United States. But just to

get a radio signal does not tell us much about the satellite's location. Directional antennas at special receiving stations and radar are used to pinpoint its position.

Information from these radio stations is sent almost at once to a computing center. There the data are fed into a giant electronic computing machine that works out minute-by-minute positions over the earth at a rate 150 times faster than the satellite moves! Without such computers, finding the path of a satellite would be almost impossible.

For the satellite program of the United States a dozen special sky cameras were designed and made (Fig. 90). A sizable section of the sky is recorded on each picture; on it the moving satellite shows as a series of little streaks. Then the position of the satellite compared to the stars can be found very accurately at a known time.

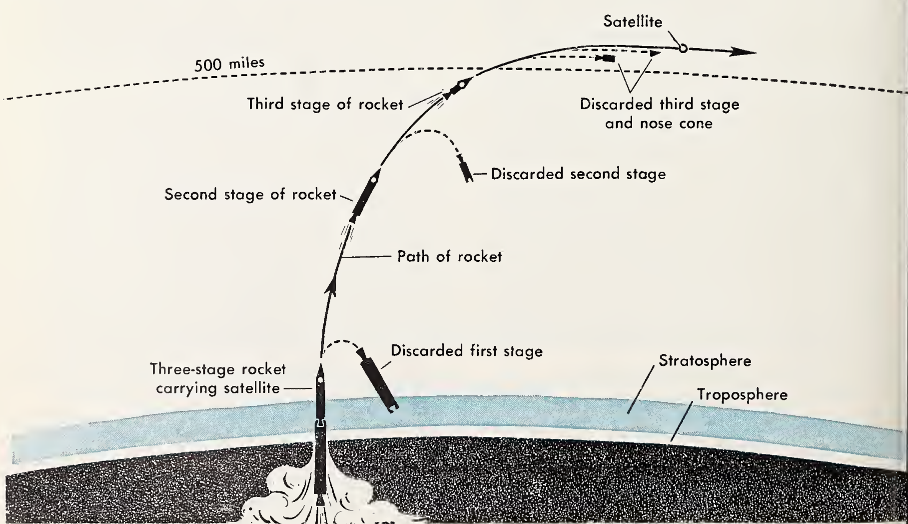
Many groups of trained observers also watch by eye to help get the first observations. Their effort is known as *Operation Moonwatch.*

Have you seen an earth satellite or the larger, brighter final rocket? Most of the actual satellites discussed above are only a few feet across. From several hundred miles away they are not bright enough to be seen without binoculars or a telescope. But along with the satellite itself, the final rocket stage also goes into orbit. Since the rocket is usually much larger than the satellite, most sightings have been of the brighter rockets. They look like a brightish star moving across the sky in a few minutes. Sometimes they change in brightness because the rocket is spinning.

Viewing Satellites

Satellites or their rockets can be seen only during twilight. The reason

89 A three-stage rocket is needed to send a satellite beyond the earth's atmosphere and into orbit at a desired distance. How fast must the final stage of the rocket be moving for the satellite to go into orbit? How far from the earth?



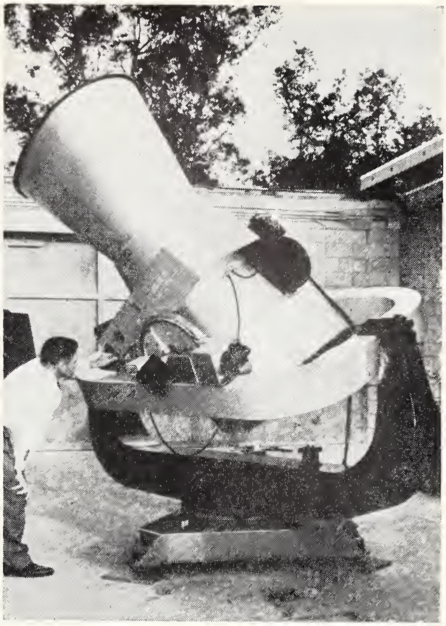
is that, in the daytime, the satellite or rocket is not bright enough to be seen against the sunlit sky. In the middle of the night the satellite is in the shadow of the earth and has no light to reflect. Only when the satellite is in sunshine and we below have a dark sky can we see it. This occurs during morning and evening twilight (Fig. 91).

The first American satellites were fired from Cape Canaveral in Florida, which has a latitude of about 28½° north. Fired toward the southeast over the Atlantic Ocean, where the first-stage rockets can fall without damaging anyone, the satellites must go as far south and back north as the latitude of the launching site. That is, those American satellites *must* move between 28½° north and 28½° south. They could be fired directly north or south and would pass over both poles of the earth. Such a direction would lose the useful effects of the earth's rotation, which at Cape Canaveral is about 900 miles per hour eastward.

The Russian satellites are fired from the middle of Asia. Since this firing place has a latitude greater than 50° north, their rockets go farther north and south than our first ones did. As a result people in the populated latitudes between 30° and 60° were able to see the Russian satellites or their rockets, but not those from the United States.

What Have Satellites Revealed?

After all the bother and expense, what have we learned from the first satellites? While not all the results are completely worked up and published, some very interesting ones are known and more will come.



PERKIN-ELMER CORP.

90 One of the specially designed cameras for tracking a satellite. When properly adjusted, it can record the progress of a satellite across the sky.

The Sputnik dog Laika lived for ten days in a satellite. This showed that a complicated animal like a dog — perhaps even a man — could survive the speeding up of rocket take-off and the condition of being weightless. For ten days it survived *cosmic rays*, the particles of great energy that seem to come from outer space. Also, the temperature within the satellite was kept within "living range."

Rockets have reported that cosmic rays are much more intense than we had believed. This unexpected abundance begins at around 600 miles and is strongest between 5,000 and 10,000 miles out. Then the amount becomes less. Possibly it is associated with the auroras (northern lights)

and very likely also with "radio blackouts."

At a height of 135 miles the air is 9 times thicker than had been expected. Such a result is found from the unexpected rate at which satellites slow down when they pass through the lowest part of their orbits.

Two major results might go unnoticed. First, man has been able to get bodies into space and flying around the earth for weeks, months, or years. Second, by very careful design, small instruments are able to measure a large variety of conditions in space and, by radio, relay the results back to earth.

Finally, the possibilities of getting men into space have ceased to be an idle dream and have become realizable.

SOME PROBLEMS OF ROCKETRY

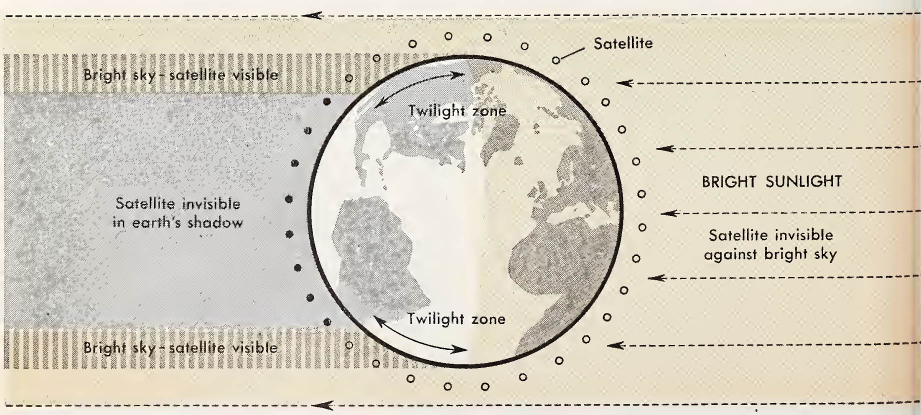
To appreciate the problems of rocketry we must examine carefully some of the difficulties.

Thrust

You know that the earth pulls on everything on its surface with a force called gravity, or "one *g*." This pull on you is your weight. To throw a ball into the air, you must first pick up the ball by overcoming its weight. Then you have to give it a larger push to send it flying above your head. So it is with a space ship or satellite. We must first build up a push equal to its weight; then a much greater push is needed to get it going at the speed of several thousands of miles per hour needed to rise far above the earth.

A jet engine or rocket moves forward because it blasts material backward very rapidly. The difference between a jet and a rocket is that a jet must take in oxygen from the air to burn its fuel while a rocket carries its own oxygen. A rocket works best in a vacuum where there is no air resistance. It does *not* need to push against anything. The basic law demonstrated by a rocket is known as *Newton's Third Law*, which states: *To each action there is an equal and opposite*

91 Why is a satellite or the final stage of its rocket visible only in the morning and evening hours?



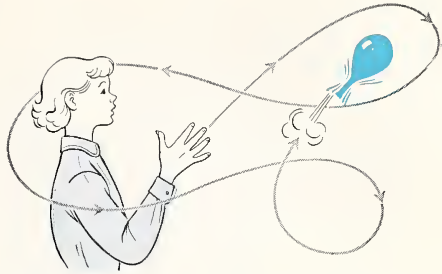
reaction. As hot gas rushes backward from the rocket, the solid part is pushed ahead. You can see this by many simple experiments like that suggested in Fig. 92.

To get enough *reaction* from a rocket even to equal its own weight, let alone push it forward, it must eject much material in a short time and at a high velocity. This means the fuel must burn very rapidly. The hotter it is, the faster its molecules will move and the more push, or *thrust*, results. So you need a very high temperature in the firing chamber. That is why special materials are used, and even better ones wanted. Also, the nozzle must be designed so that the outflowing gases will all be moving in the same direction. Poor nozzle design can waste the thrust from fuel.

When you realize that a big rocket costs over a million dollars, you can see why each is carefully designed and manufactured. Some rockets include over 30,000 working parts, all of which must do what they are supposed to do and do it at the right time. Guesswork will not get a rocket into the air. Careful design, the use of much knowledge, long mathematical calculations, and highly skilled work plus careful testing are essential.

Gravity

You know that the pull of the earth, or gravity, causes falling bodies to speed up the longer they fall. Such a speeding up is called *acceleration*. Each second a falling body speeds up by the same amount no matter how fast it is already going. If you let go of a body, say from the top of a high cliff, at one second it will be falling at a speed of 32 feet per second; at two seconds its speed will be 64 feet per second; and at three seconds, 96 feet per second.



92 The balloon goes forward (reaction) with a force equal and opposite to the force of the escaping air. This illustrates the way in which rockets and jet planes are able to fly. Try this at home.

How far a body will fall in one, two, or three seconds depends on its *average* speed over the whole time of fall. In one second it will fall only 16 feet because its average speed is $\frac{0 + 32}{2}$ or 16 feet per second. In three seconds, however, the distance fallen will be 3 seconds $\times \frac{0 + 96}{2}$ or 3×48, which is 144 feet. In Table 5 you can see the relation between the time of fall, the velocity at the end of the time, the average velocity over this time, and the distance fallen. Notice that we have neglected air friction, which is not important for small round bodies moving at low speeds. But air friction goes up very rapidly as the speed increases and has a large influence upon cannon shells and high-speed rockets.

How does gravity affect a body moving upward? You know that a ball thrown into the air will gradually slow down, finally stop rising, and then fall back to the ground. Each second the earth's downward pull takes away just the same amount of

TABLE 5 Rate of Fall

Time (seconds)	*Velocity* *Final (feet per second)*	*Average (feet per second)*	*Distance Body Falls (feet)*
0	0	0	0
1	32	16	16
2	64	32	64
3	96	48	144
4	128	64	256
5	160	80	400

If you make graphs relating time to the other quantities, you will have some interesting curves. From them you can tell how high a baseball went and how fast you threw it by measuring the time it was in the air. The "time of rise" or of "fall" is half the total time for "up and down."

speed from a rising body that it adds to a falling body. The same rules apply in both cases.

If we could start a rocket with a speed of one mile (5,280 feet) per second or 3,600 miles per hour, it could go about 83 miles high. Its travel time would be about 330 seconds, or 5½ minutes. Because it actually starts off slowly and speeds up, the total time would be a bit longer. A rocket with about this speed, altitude, and flight time was the German V-2.

Newton's Apple — and Rockets

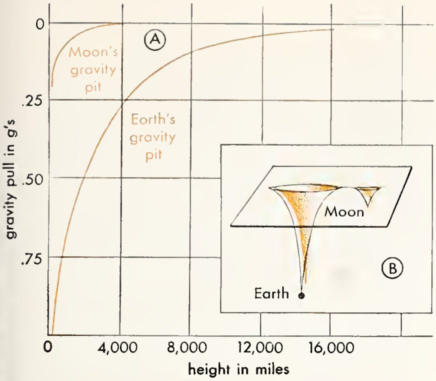
You know that Isaac Newton wondered why the moon did not fall to the earth like an apple did. He believed that the earth was pulling on the moon as it did on the apple, but by a much lesser amount because the moon was far away. He knew of no force pushing the moon away; therefore it ought to fall. But it didn't — or did it?

Newton knew that the moon was moving sideways to the earth's pull at about ⅔ of a mile each second along its path around the earth. He also knew that a body tends to stay set or to keep moving in a straight line unless pushed or pulled. This tendency for a body to keep on moving in a straight line, or to keep standing still, is called *inertia*. You have experienced inertia when your auto stopped quickly and you tended to keep moving fast and may have lunged forward. Newton saw that the moon would need to fall toward the earth only 0.0045 feet (or 1/20 of an inch) each second to "fall around the earth" in the path it actually takes. This amount of fall each second was just the amount it would fall if the earth's pull died away at the rate indicated in Table 6. In this way, by studying the motion of falling bodies like apples, of the moon around the earth, and of the planets around the sun, we have learned the rules by which rockets or other bodies will move.

Only 1,660 miles above the earth's surface the acceleration of gravity is just half what it is where you are on the earth's surface. Table 6 shows how fast this pull decreases with distance.

If we were to make a picture of how strongly the earth's pull dies out with distance, we would have a graph like that in Fig. 93. You might think of this as the earth's "gravity pit." For comparison, the moon's shallower gravity pit is also shown.

In many ways sending up a rocket is like rolling a ball up a rounded roof. We start it with a big push. At first, it slows down rapidly because the roof is steep. Then it slows less rapidly because the slope is less. A



93 The earth's pull of gravity is greater than the moon's because the mass of the earth is greater. Can you see how the pull of gravity becomes less with distance and why it would be easier to escape from the moon's pull?

TABLE 6 Pull of Earth and Moon Compared

Altitude above Surface (miles)	*Earth's Pull in g's*		*Moon's Pull in g's*
0	1	or 1.000	0.167
1,660	1/2	0.500	
4,000	1/4	0.250	0.0075
8,000	1/9	0.111	
12,000	1/16	0.063	
16,000	1/25	0.040	

If you want to make your own table of different distances, the pull lessens in proportion to the *square* of the distance from the *center of the earth* or *moon*.

rocket will "go over the top" if we give it a speed of 7 miles per second, or 25,000 miles per hour. This is called the *velocity of escape*.

If you read fanciful stories about rockets escaping from the solar system and moving off towards other stars, remember that to escape from the *sun's* pull a rocket from the earth would have to reach an escape velocity of 26 miles per second, nearly four times the speed needed to get it away from our little earth. Remember also that even the nearest star is so far away that light, at its tremendous speed, takes over four years to reach us. Don't confuse what we know with fanciful stories written to be entertaining.

Multi-stage Rockets

To get a space ship completely away from the earth will be difficult. However, by putting several strong rockets together "piggy-back," or in stages, very high speeds have been reached by the small nose sections. This is the way the earth satellites have been launched.

Each section, or stage, is a rocket with its own fuel and burning chamber. When the fuel tanks are empty, they are of no more use. Instead of trying to speed up all this useless weight, the burned-out part is cast off and falls to the earth. Then the next stage burns its fuel and speeds up rapidly. The Sputniks, Explorers, Vanguards, Pioneers, and Mechtas have all been lifted by multi-stage rockets.

The first stages of such rockets are really enormous. Yet the final pay load is very small. To launch a rocket that can carry a man or two in the nose section, with all the things a man would need to stay alive for days or weeks, requires an enormous thrust from a huge rocket.

Fuel

The biggest problem is to get up a high speed in a short time. Fuel is

heavy and every pound has to be lifted by the burning of other fuel. We need a fuel with a big punch — one that will give very high temperatures and a big push per pound.

At present most rockets are powered by liquid fuels and liquid oxygen. But all such liquid-fuel rockets have basic limitations. The chemicals are very dangerous and must be handled with care. Pumps and tubing are needed in the rocket to supply the fuel and oxygen at the right rate. By a recent development the rate of burning can be changed and the fuel used more efficiently.

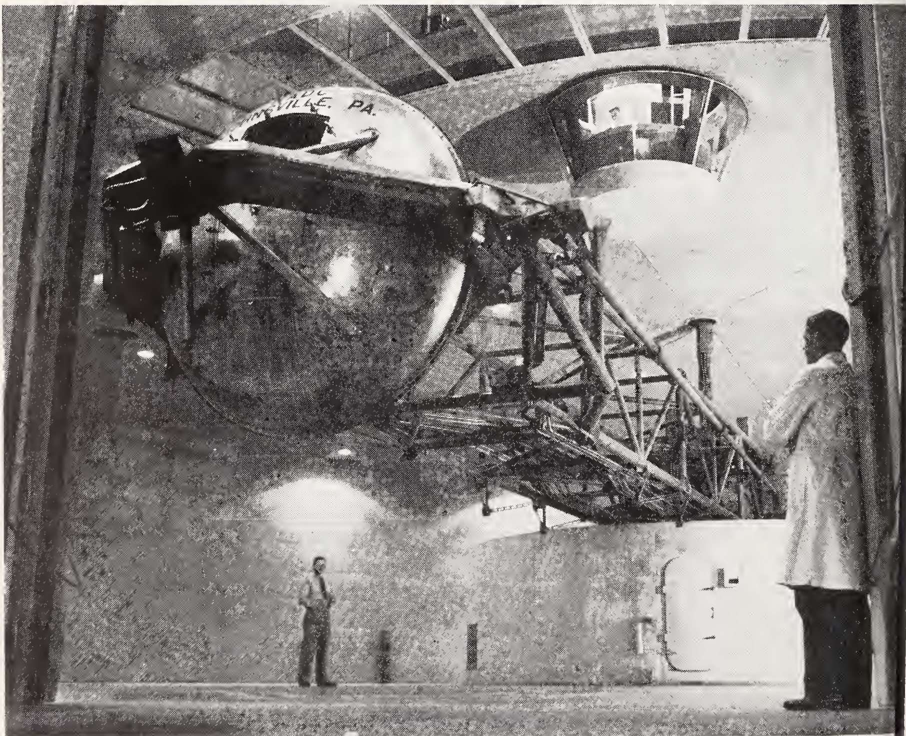
Solid fuels seem promising because they can be loaded long in advance and need no pumps or tubing. But at present we have no announced solid fuel that will give the push of our liquid rockets. Here is where the work of the chemist is important in developing new fuels.

Nuclear power for a rocket or space ship has received much study. A nuclear reactor would provide very high temperatures without the necessity of carrying oxygen to burn a fuel. This would be useful, although the reactor itself would be fairly heavy.

Also, the material to be pushed out must be carried. Therefore, such a rocket engine could operate only for a limited time unless new ejection material was supplied.

94 In Johnsville, Pa., the U.S. Navy whirls its would-be space men in this machine to find out how great a pull of gravity they can stand.

U.S. NAVY



The Human Barrier

Can men stand the forces and conditions of rocket flights into space? These questions have been studied by doctors interested in space medicine. By whirling men in giant machines that copy the forces of rocket take-off, they find that men can stand such strains (Fig. 94).

While we probably can meet the bodily needs of man in space, there is real concern for his reaction to the cramped quarters he would occupy and the isolation he would have. Laboratory experiments with volunteers have shown that carefully chosen men can stand these conditions for as long as two weeks. Through such experiments we have learned of the wonderful abilities of the human being to withstand great changes in his environment.

How to protect man from the possibly serious effects of cosmic rays in space is still unanswered. From the first satellites we have learned that these high-speed atoms and bits of atoms are more numerous beyond the earth than had been thought. Like X rays and radioactive particles, they cause major changes in some of the cells of the body. Surely no one wants to expose a human being to conditions that might give him cancer or shorten his life by much. But these particles, or rays, will go through several feet of lead and no practical way to shield them off is yet known.

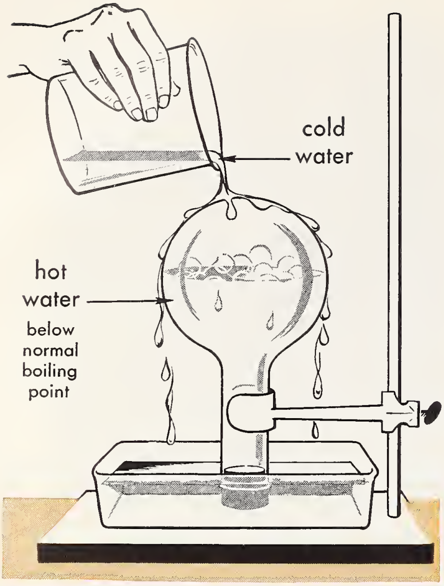
Whenever the rocket would not be accelerating, a passenger would be *weightless*. He and the rocket casing would be moving under the same pull of the earth and he would not push against the rocket. How men will react to weightlessness is difficult to explore. By diving high-speed aircraft in a particular way, for as long as a minute the pilot and passenger are almost weightless. After some mild upset on the first few flights, most of the experimenters learned to adjust to the new conditions and perform test manipulations. Their basic bodily functions — breathing, heartbeat, blood pressure — were normal. Mice and monkeys shot up in rockets have also behaved normally.

We do not yet know how a human being will react when weightless for hours or days. The initial sensation seems to be that of floating, which changes to the feeling of falling. Unless this were overcome through training, panic and possibly insanity might follow. Among the many hazards of space flight this is a serious one about which we are unable to gather much information.

We do know that a space passenger must be supplied with oxygen and have his body kept under pressure. The air thins out rapidly with height. At only 3½ miles half of the atmosphere has been passed. During all high-altitude flights extra oxygen must be supplied.

Just supplying oxygen is not enough to keep a man alive. His lungs and whole body are accustomed to being under the pressure of air at 15 pounds per square inch. If this is removed, his blood will boil.

In your classroom your teacher can show you the effect of lowered pressure on the boiling point of water. We say "your teacher" because he knows how to show this safely without danger from broken glass. He will be sure to use a strong round-bottomed flask like that shown in Fig. 95. As he pours cold water over the upturned bottom of the



95 Water boils below 212° F. when the pressure on its surface is lowered. Cooling changes the steam inside the flask to water. The water takes up less space than the steam. The pressure becomes less, and the water boils under the lower pressure.

flask, which was stoppered after the water in it was boiling, he cools the water and vapor inside. This lowers the pressure inside the flask. Does this cause water to boil as the pressure above it falls?

You can see why a space suit is very important. For the pilot of the X-15 who will fly to a height of nearly 100 miles the Air Force and Navy developed a new, lightweight suit. This required 2½ years of work and cost $200,000. But where the old suits weighed nearly 100 pounds, this one weighs only 13 pounds. The makers believe that in it a man could go to the moon and back, if the trip did not take too long.

How Might a Space Ship Land?

You have seen how difficult the launching of a man-carrying space ship would be. But how are we to get such a passenger back? In the movie and fiction versions, rockets carry plenty of extra fuel. As they near the moon or the earth, they turn around, put on the rocket motors, and "back down" against gravity. While such rockets may become possible, at present we have barely enough thrust to get the rocket going up.

Some sort of wings for the rocket nose might be useful. On coming into the upper air such a rocket might dive in and then pull up, roller-coastering gradually down. This should slow down the rocket by air friction and keep it from burning up like a meteor. The X-15 rocket plane, designed to study *re-entry* into the atmosphere, will test this procedure. Calculations indicate that even at its relatively low speed it will probably heat up to a temperature of nearly 1,000° F.

Wings would not aid a landing on the airless moon or on Mars. Some sort of reverse-rocket method seems necessary. To offset the moon's weak pull either on landing or taking off, only 1/25 as much fuel would be needed as for getting away from the earth.

Space Stations Ahead?

So many developments that seemed almost impossible have already occurred that it is difficult to forecast what to expect in the future. For man to explore the moon and possibly the nearer planets, Mars and Venus, would be very exciting. Even now, going all the way on one set of rockets might be done. However, it would

take very large rockets and be very expensive.

Imaginative people like Drs. Wernher von Braun and Willy Ley have suggested that a *space station* about a thousand miles above the earth would be a very useful observing place. Also it could be used as a base for the assembly of real space ships that did not have to go through the earth's atmosphere. At a height of 1,000 miles a satellite would go around the earth in just about 2 hours.

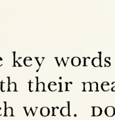
Even our present three- and four-stage rockets get that high. But the final part of the rocket containing the needed material, the pay load, is now very small. Stronger fuels, which may be produced soon, might make larger pay loads practical.

One design for a possible space station shows a great doughnut-shaped satellite 260 feet across. Living quarters would be in the outer rim. By spinning the wheel, some sensation of "weight" would occur in the outer sections. Great collectors of sunlight would provide plenty of energy to be trapped and held. Possibly ways might even be found for manufacturing rocket fuel in such a space station. Plants, probably one-celled algae, might be grown to provide both food and oxygen. Supplies would be sent up on special "freight car" rockets.

If you look back at Fig. 93, you will see that a satellite 1,000 miles high would already be a good part of the way up the earth's "gravity pit." Less fuel would be needed to start a space flight from this platform than from the earth below.

Surely you will wish to read further about possible space stations. Also you should consider what conditions would be essential for men to live in such a station.

You can see that any such station would be very expensive. Only the whole country through our government could possibly finance such an effort. Whether or not it is ever tried is up to you. You will pay the bills. You may help in the design and construction. You may be among the few who put it together and live there. You may be the voyager who first lands on the moon, on Venus, or on Mars. Your future depends greatly upon science and how it is applied.



LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings opposite them by writing the correct meaning listed below after each word. DO NOT MARK THIS BOOK.

velocity of escape	pay load	space station
weightlessness	thrust	cosmic rays
reaction	acceleration	satellite
apogee	IGY	inertia
perigee		

1. the amount of useful material carried up by a rocket
2. the point in an orbit farthest from the earth
3. a change in speed or direction
4. the sensation of being without support, a problem in space travel
5. particles of great energy that seem to come from outer space
6. a rocket that takes up an orbit around the earth like a tiny moon
7. velocity at which a rocket will escape from the gravitational pull of a large body (earth, moon, sun)
8. the tendency for a body to keep moving in a straight line, or to remain at rest
9. the push on a rocket caused by gases shooting out from the other direction
10. the amount of push given a rocket by its burning fuel
11. the point in an orbit nearest the earth
12. a large satellite in which men might live
13. initials for a large international study of the earth and the space around it

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. The first rocket to reach a high altitude was fired about . . . .
2. Four reasons for exploring space are *a* . . . , *b* . . . , *c* . . . , *d* . . . .
3. The basic law describing how a rocket operates is . . . . . . Law.
4. In each second a falling body near the earth speeds up by . . . feet per second.
5. When we say the "moon falls around the earth," we mean . . . .
6. The tendency of a moving body to continue in a straight line is called . . . .
7. The velocity needed to escape from the earth is . . . miles per second; to escape from the solar system after starting from the earth it is . . . miles per second.
8. Rockets that reach the highest speeds are now all . . . rockets.
9. Three major dangers faced by a space man are *a* . . . , *b* . . . , *c* . . . .
10. Your blood will boil if . . . .
11. For you to be able to see a rocket or satellite, the sky must be . . . and the rocket or satellite must be . . . .
12. Computations of future positions of satellites are made more rapidly with . . . .
13. In the study of rockets and satellites, we can separate the . . . motion from the . . . motion.
14. A satellite must go at least as far north and south of the equator as the . . . .

GOING FURTHER

Projects

1. From your extra reading about satellites and the conditions in space, make a careful list of the conditions and things necessary to keep a man alive for several weeks in a space station.

2. Arrange a debate on the issue: "Resolved, that the government should appropriate the money needed to construct and maintain a space station."

3. From the figures in the table, make a graph relating the average height of a satellite to its period around the earth.

4. Explore the possibilities of making your own observations of satellites. For suggestions, see articles such as that in the *Scientific American*, January 1958, page 98.

In the Laboratory and Field

1. To show the nature of the reaction principle on which all jets and rockets work, place a well-oiled child's wagon or scooter on a smooth level surface. One person steers, and another sitting back to back acts as the "rocket engine." Place on the wagon a number of bricks or sizable stones. When the "engine" throws the stones backward in rapid order, the wagon will move forward.

2. With this same arrangement, the blast from a large CO_2 fire extinguisher can be used as a jet. Do not point it at any animal or person. Fire it in short blasts or you will go too fast.

3. See what weight can just be raised by a CO_2 fizz cartridge. Insert the cartridge tightly in a hole bored in the middle of one side of a block of wood. Set this over a hole in a stand like a ring stand. Fire the cartridge by punching a hole in the thin end with a nail from underneath. Weights can be fastened to the block to test relationship between weight and the distance the block will move. Fizz cartridges of compressed CO_2 can be bought at hobby shops, and at grocery, hardware, or drugstores.

4. Fire a jet model auto or rocket plane along a wire, using a fizz cartridge as the engine. In the model put two screw-eyes — at the front and the back as shown in the drawing at the foot of page 202. Run a strong wire through them and hitch the wire securely at both ends about 25 feet apart. Push the fizz cartridge into a hole in the rear of the model.

Table relating average distance from center of earth, average height above the earth, and period of a satellite.

Average distance from Center of Earth (*miles*)	*Average height Above Earth* (*miles*)	*Period Around Earth* (*hours*)
4,072	113	$1^h\ 28^m$
4,134	175	1 30
4,286	327	1 35
4,435	476	1 40
4,581	622	1 45
4,726	767	1 50
5,008	1,049	2 00
5,282	1,323	2 10
5,550	1,591	2 20
5,811	1,852	2 30
6,066	2,108	2 40
6,562	2,603	3 00
7,272	3,313	3 30
7,949	3,994	4 00
9,224	5,265	5 00
14,643	10,684	10 00
19,187	15,229	15 00
23,224	19,285	20 00
26,248	22,289	24 00
44,000	40,000	52 06
239,000 (the moon)	235,000	656 00

Fire it by punching a hole with a sharp nail or with a needle gun you may be able to buy at a hobby shop. The model may go as fast as 30 miles per hour. At the end of the run catch it in a soft pillow. *Caution:* Keep out of the way of *both* ends of the model when you fire it.

Adding to Your Library

There are many books on space travel and rocketry and more being published constantly. A few that you may enjoy reading for information or for hobby experiments are listed here.

1. *Rockets, Satellites and Space Travel* by Willy Ley, Random, 1958. An easy-to-read book by one of the pioneers of space study.

2. *The World in Space* by Alexander Marshack, Nelson, 1958. A report on the IGY.

3. *The Making of a Moon* by Arthur C. Clark, Harper, 1958. Lively presentation of how satellites are constructed, what equipment they carry, how they are launched, and how important they are.

4. *Rocket to the Moon* by Erik Bergaust and Seabrook Hull, Van Nostrand, 1958. Good reading.

5. *Complete Book of Space Travel* by Albro T. Gaul, World, 1956.

6. *Exploring Earth and Space* by Margaret O. Hyde, McGraw, 1957. The story of the IGY.

7. *Man into Space* by Hermann Oberth, Harper, 1957. The author was one of the first to write a practical guide to rocket travel.

8. *Handbook for Observing the Satellites* by N. S. Howard, Crowell, 1958. A complete guide to spotting all the satellites: where to find them and what equipment to use.

9. *The Space Frontier, with Astronautics Glossary*, a 24-page booklet on conditions in space near the earth and at great distances. Over 200 special terms are defined in the glossary. National Aviation Education Council, Washington, D.C.

10. *All About Satellites and Space Ships* by David Dietz, Random, 1958.

11. *Secrets of Space Flight* by Lloyd Mallan, Arco, 1956. Illustrated.

12. *Earth Satellites* by Patrick Moore and Irving Geis, Norton, 1958. Illustrated.

13. *Satellite* by Erik Bergaust and William Beller, Hanover (Doubleday), 1956. Information on relation of satellite program to International Geophysical Year.

14. *The Conquest of Space* by Chesley Bonestell and Willy Ley, Viking, 1949. This book takes you as close as possible to objects in space with pictures drawn by an artist-scientist. An early book taking a long look into the future of space travel.

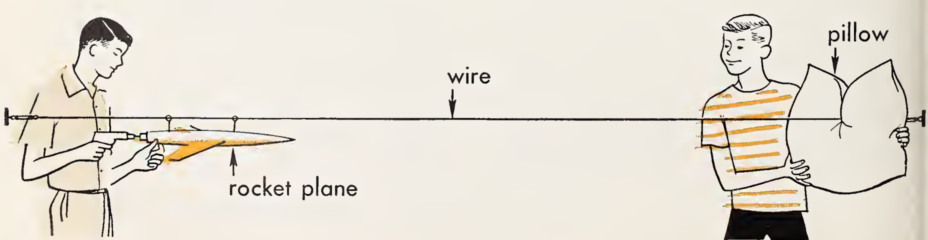
Careers for You

You may or may not become a space traveler, but you may become a scientist who does the research that is needed. Is a career in scientific research for you? Visit a research laboratory or invite a *research scientist* to visit your class. Find out what kind of training is needed and what a research scientist does each day.

A Bit of Research

Using the books listed above, prepare a list of as many facts about man's attempts to reach high altitudes as you can find. Compare your list with those of other members of your class. Pool your knowledge and then prepare a large wall chart for your science room. On it show what is known about man's attempts to get up into space. Other committees may want to make lists of true and false ideas about space travel. Others may want to prepare for a debate on the topic: "The United States should get started now on an all-out attempt to set up a space station regardless of cost."

96 When the seal of the gas cylinder in the tail of the rocket-plane model is broken, the force of the escaping gas (action) will drive the plane forward (reaction) at a speed of 30 to 40 miles an hour. This is the reaction described by Isaac Newton. Read the hobby section on making model airplanes beginning on p. 527.



MODEL ROCKETS AS A hobby

All over the country young people have been trying to make their own rockets, often at home in the basement. Also, all over the country there have been numerous and very serious accidents to some of these young people. *A rocket is not a toy.* The chemicals that will send it upward may go off at unexpected times. If you want to experiment with rockets and perhaps fire them, the first step is to get your parents' permission and if possible some supervisory help from them or at least from an older person who is interested. The next step is to get all the help and advice you can from the many groups who know how to handle rockets safely. Only then should you start work on your rocket project.

To succeed, you must have: 1. a knowledge of the hazards; 2. expert supervision; 3. a safe working area. If you do not have *all three* conditions — DON'T PLAY WITH ROCKETS.

There is, of course, a great thrill in seeing a rocket you designed and made soar into the air (let us repeat, *in a safe area*). But there is much more to rocketry than just sending rockets up.

Many good scientific studies can be made on rockets that never fly; they are fired on a fixed, static stand. Tied down securely, they can give information on the thrust of various fuel combinations. They can provide information on the best rate of burning. Also, they can help you find the best design for the all-important nozzle. The nozzle must be just right or the rocket won't function properly — or not at all!

Two books that you will find useful if you decide that rocketry is the hobby for you are:

Model Jets and Rockets for Boys by Raymond F. Yates, Harper, 1952. It tells how jets work, where to buy model materials, suggests home experiments, and discusses the best ways to fly jets.

Rockets into Space by Alexander Joseph, Science Research Associates, Chicago, 1955. This book has many experiments in it for the classroom.

There are many groups that are willing and ready to help young people interested in rocketry as a hobby or a career. Write to them for advice. Among these are:

The United States Air Force
The United States Army, Ordnance Department. (Contact your nearest military establishment or reserve unit.)
Southwest Rocket Society, P.O. Box 7827, University Station, Austin, Tex.
The Rocket Research Institute, 3262 Castera Avenue, Glendale 8, Calif.
Science Clubs of America, Washington, D.C.
American Rocket Society, Inc., 500 5th Ave., New York, N.Y.
Atlantic Research Labs. Corp., 29–05 40th Rd., Long Island City, N.Y.

UNIT 4

Understanding the Earth's Weather

Clouds, winds, lightning, rain — these were forces that the ancients recognized and often feared but could do little about. Today weather observers gather information around the clock and predict — with surprising accuracy — what to expect for twenty-four hours or more ahead.

What do you need to know about weather? That depends. A farmer needs to know enough about it to protect his animals and crops. The home-builder selects materials to meet general weather conditions so that the house may be a package of perfect weather. If there are violent weather changes, the clothing you wear is important. The person who remarked that everybody talks about weather but nobody does anything about it was witty but wrong.

Wherever you live, whatever you do, weather is important to you. This will help you understand the role weather plays daily in your life.

Your Science Inventory

How well do you already understand the earth's weather? Copy the following questions in your notebook and write your best answer for each one. When you finish studying the unit check your answers to see how many you had right.

1 Your shadow is longest on (a) March 21, (b) June 21, (c) September 21, (d) December 21.

2 Seeding clouds is an artificial way to (a) cause lightning, (b) cause rain, (c) destroy insects, (d) plant crops.

3 If you feel a breeze blowing from the sea toward the land, you know that (a) both land and sea are the same temperature, (b) the land is cooler than the sea, (c) the sea is cooler than the land, (d) there will soon be a storm.

4 In the horse latitudes you would expect to find (a) calm weather, (b) stormy weather, (c) north winds, (d) south winds.

5 The highest temperatures are thought to occur in the (a) ionosphere, (b) stratosphere, (c) troposphere.

6 A barometer is used to measure (a) air pressure, (b) temperature and pressure, (c) mercury pressure, (d) water pressure.

7 If you noted that a barometer was falling rapidly, you would expect (a) cold weather, (b) fair weather, (c) hot weather, (d) a storm.

8 The highest winds are registered in a (a) gale, (b) hurricane, (c) storm.

9 Scientists use a sling psychrometer to find the (a) air temperature, (b) relative humidity, (c) best thermometers, (d) air pressure.

10 Days and nights are equal all over the earth (a) once a year, (b) twice a year, (c) four times a year, (d) at no time.

11 A refrigerant causes rapid cooling because it (a) condenses rapidly, (b) has a low boiling point, (c) has a low freezing point, (d) melts rapidly.

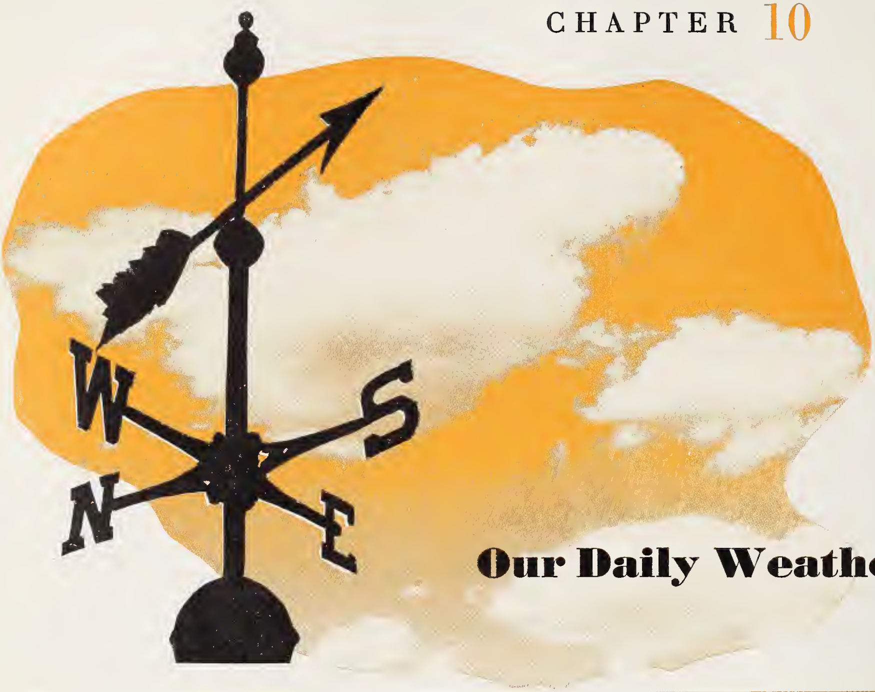
12 Insulation in the roof of a house causes the temperature inside to be (a) higher all year around, (b) higher in summer and lower in winter, (c) lower in summer and higher in winter, (d) lower all year around.

13 Spontaneous combustion is caused by (a) convection, (b) insulation, (c) oxidation, (d) radiation.

14 A fire in a fireplace heats a room mainly by (a) conduction, (b) convection, (c) conduction and convection, (d) radiation.

15 A heavy dew in the morning indicates that during the night it was (a) clear and calm, (b) clear and windy, (c) below freezing, (d) raining.

CHAPTER 10



Our Daily Weather

Rain? Snow? Cold? Hot? Sunny? Hail? Hurricane? Gale? Thunder? Lightning? What was the weather today? Whatever it was, it played and will play a part in your life. What makes the weather?

We may be enjoying October's bright blue weather, or we may be soaked to the skin by a sudden rainstorm. At both times, we may wonder what makes the weather. There is no simple explanation. Sometimes the weather is a hurricane or tornado, so frightful that we find it almost beyond belief. At other times, the weather is mild and sunny, with gentle breezes which invite us to spend our time outdoors. All kinds of weather changes are caused by air in motion. What causes changes in the motion of the air? How does the motion of the air bring about changes in our weather?

OUR OCEAN OF AIR

We live at the bottom of an ocean of air called the atmosphere. It is always in motion. When you have discovered what makes the air ocean move, you will be well on your way to understanding what makes the weather change.

Air in Motion

To begin with, let us try to set just a roomful of air in motion. How would you do it? You might open a window and a door, making a draft, or you might turn on an electric fan. Even the heat from an electric light bulb can start air moving (Fig. 96). Have you ever noticed how the air seems to dance over a hot stove or radiator? Have you ever felt the draft caused by air rushing up a chimney from a roaring fire in a fireplace?

A simple experiment will show you what happens when air is heated.

Stretch the neck of a toy balloon until it fits over the top of a small flask. Now heat the flask gently on an electric hot plate. You will notice that the balloon begins to grow larger. Why? Of course, you know that no more air can enter the flask and the balloon. Therefore, if the balloon is larger after the flask is heated than before, the explanation must be that heating the flask makes the air take up more room, or expand. Why?

To find this answer, you must remember that air is a mixture of gases. Everything in the world, including these gases, is made up of small parts called molecules (Unit 5). In a gas the molecules are able to move around more freely than in a solid such as a piece of stone. In air the molecules are fairly far apart, but in stone they are closer together. Molecules are too small even to be seen under an ordinary microscope, and so it is impossible, of course, to see them in the air. Scientists, however, have proof that air molecules do move.

When a gas is heated, its molecules

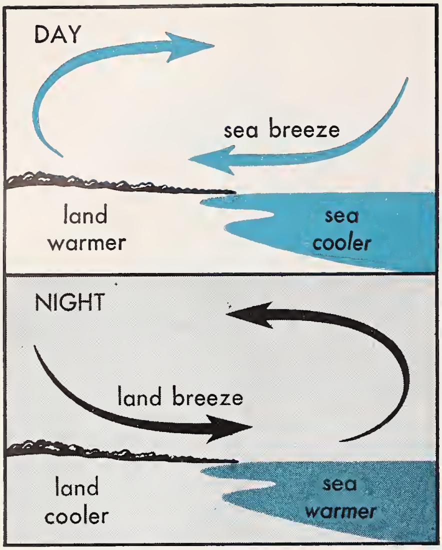
96 The turning of the vanes shows that the hot air above the lamp bulb is rising. *Exhibit:* From a piece of tin can, make a wheel like the one above and show your classmates how it works.

move faster and thus move farther apart. They take up more room. To put it another way, gases expand when heated. Furthermore, scientists know that a certain amount of heated air weighs less than an equal amount of cooler air. Therefore, heated air is forced to rise as cooler, heavier air moves in under it.

Now you know why the air above a hot stove seems to dance. It is rising. As the air is heated, it expands, becomes lighter, and is pushed upward by the cooler air moving in under it. Now let us see what happens when air over many parts of the earth is heated.

Temperature Differences Make the Wind Blow

Have you ever visited the seashore on a summer day? You may have noticed a cool breeze coming from the sea toward the land (Fig. 97). How can you explain where this cool sea breeze came from?



97 A sea breeze by day and a land breeze at night are common along seacoasts. The land and its air warm up faster than the ocean, and also cool off faster.

You can get some facts by feeling the dry sand on the beach and the water in the ocean. The dry sand feels hot, doesn't it? If you dip your feet into the water, you think it feels cold, even icy. Actually the water is far above freezing — probably around 60 to 70° F. By now you must know why the breeze is blowing from the sea toward the land. The sea is colder than the land. The air over the land becomes heated like the air around a hot light bulb or the air over a stove. The heated air rises when the cool air over the water moves in under it to push it up. This is the sea breeze.

Air is always being heated or cooled by the earth's surface. If two different parts of the earth's surface have different temperatures, the air above them also will have different temperatures. When there are these differences in the temperature of air, a wind is born. Watch little whirls of leaves, dust, or small pieces of paper, and you will see a tiny, small-scale wind. Not every breeze makes important weather changes, but certain winds are of great importance.

The Winds of the Earth

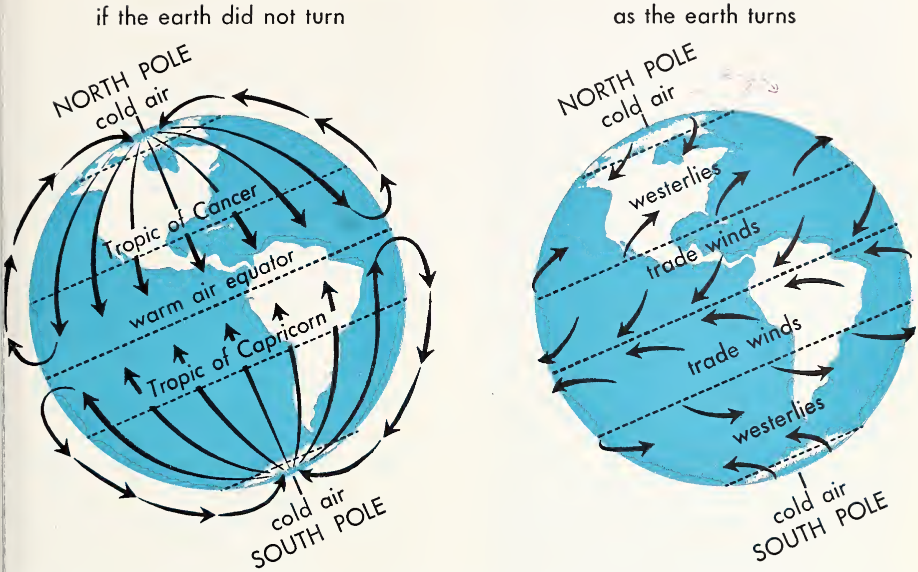
You may remember from your study of geography that winds which blow almost always from one direction are called *prevailing winds*. They blow over large parts of the earth. Some of these big winds are called trade winds. The traders of ancient times sailed the seas in the paths of these prevailing trade winds. Look at Fig. 98. It will remind you of the prevailing winds of the earth. We have prevailing westerly winds in the United States. What makes these winds blow?

There are several reasons. For one thing, the earth is round. Thus, some parts get more of the sun's heat than other parts. Wherever the rays of the sun strike the earth nearly at right angles, like this | | | | |, the earth becomes very well heated. This happens at the equator and in the regions on either side of it, called the Torrid Zone. Here this heated air rises.

In the Arctic and Antarctic regions, the sun's rays strike the earth like this / / / /, and there are long periods when the sun does not shine at all. Thus, these regions are very cold. The air above them is chilled and sinks toward the ground as it moves away from the North and South Poles.

Therefore, a movement of air begins. Hot, tropical air rises and moves toward the two poles while cold polar air is moving toward the equator

DIRECTIONS OF PREVAILING WINDS



98 The prevailing winds are the result of heat and motion. If there were only heat from the sun, the winds would all be north winds or south winds. The rotation of the earth adds a twist to these big winds, making them travel around the earth as shown.

close to the earth's surface. This movement gives us only two prevailing winds, one from the North Pole, a north wind; and one from the South Pole, a south wind. But it is not quite so simple as this.

Unequal heating may start the wind blowing, but the spinning of the earth steers the winds. The earth, as you know, rotates from west to east. This spinning causes winds in the Northern Hemisphere to be twisted to the right. Winds in the Southern Hemisphere are twisted to the left. The result of this steering of the winds is shown in Fig. 98.

Horse Latitudes and Doldrums

Other things besides unequal heat and rotation of the earth change the speed and direction of the winds. One of these things is distance. There is a great distance between the poles and the equator. The hot air of the equator has cooled a great deal by the time it has reached the Tropic of Cancer or the Tropic of Capricorn (Fig. 98). As this air cools it begins to fall toward the earth at about these points. But there is little or no motion of air across the surface of the earth at these points. Thus at or near the Tropic of Cancer and the Tropic of Capricorn there are areas of calms where for days there is no wind.

There is a story that sailing ships carrying horses to the New World were sometimes caught in the belt of calms near the Tropic of Cancer. When the wind did not blow for a week or more, the sailors had to drop the horses into the ocean to save

their short supply of drinking water. This belt of calms, therefore, got the name "horse latitudes."

A similar belt of calms at the Tropic of Capricorn has the same name. There is another area of calms at or near the equator. This is called the *doldrums* (DOL-dr'mz). When a person is not very happy we say he is in the doldrums. Sailors caught in the calms and uncertain winds of the doldrums were unhappy men.

Study Fig. 98 carefully. As you study it and read p. 209 again, be sure you can explain why the arrows showing wind direction point the way they do.

Height and the Weather

Sailors have their weather problems. Men who live in mountains and valleys far above sea level also have weather problems.

You remember that hot air rises when cooler air pushes it up. Cold air moving into a valley makes the temperature there lower than on nearby hillsides. This lowering of the temperature may bring frost that will ruin the farm crops in the valleys. Cold air staying in valleys also makes snow last longer. On some very high mountains there is snow all year long. How can this be explained?

It is true that heated air rises. However, as it rises it becomes cooler. Then the temperature of the air drops. It drops, on the average, 1° F. for every 300 feet above sea level. This drop in air temperature does not go on forever, but it does go on up to a height of about seven miles.

The atmosphere has been divided into layers. Up to about seven miles it is called the *troposphere* (TROP-uh-sfeer). In the troposphere, the weather changes which affect us day to day take place. About seven miles above the earth (the upper limit of the troposphere) there is a thin layer of air which has an even temperature of about −67° F. (67° below zero).

The layer above this thin layer in which the temperature remains the same (−67° F.) is known as the *stratosphere* (STRAT-uh-sfeer). It is a layer 10 to 50 miles above the earth. Reports obtained from skyhook balloons (Fig. 99) and from instruments sent up in rockets show that some changes of temperature take place in the stratosphere. At a height of 35 miles the temperature is thought to be about 170° F. At a height of 50 miles the temperature again drops below zero. Here the stratosphere ends and a region known as the *ionosphere* (eye-ON-uh-sfeer) begins. What is in the ionosphere is one of the major mysteries of science. Only rockets and radio waves from the earth have been there. We know its temperature rises to 1,500° F. or more. We know that it has several layers that send back radio waves in different ways. In it we see the beautiful northern and southern lights and also the trails of glowing meteors. Here we are in a region that is of more interest to spacemen (Chapter 9) than to weathermen. So let us return to the lowest level of the atmosphere — the troposphere — the one in which the weather changes in which we are interested take place.

AIR PRESSURE

The weatherman is as much concerned with air pressure as with air temperature. That is because the pressure of the air affects our daily weather in many ways.

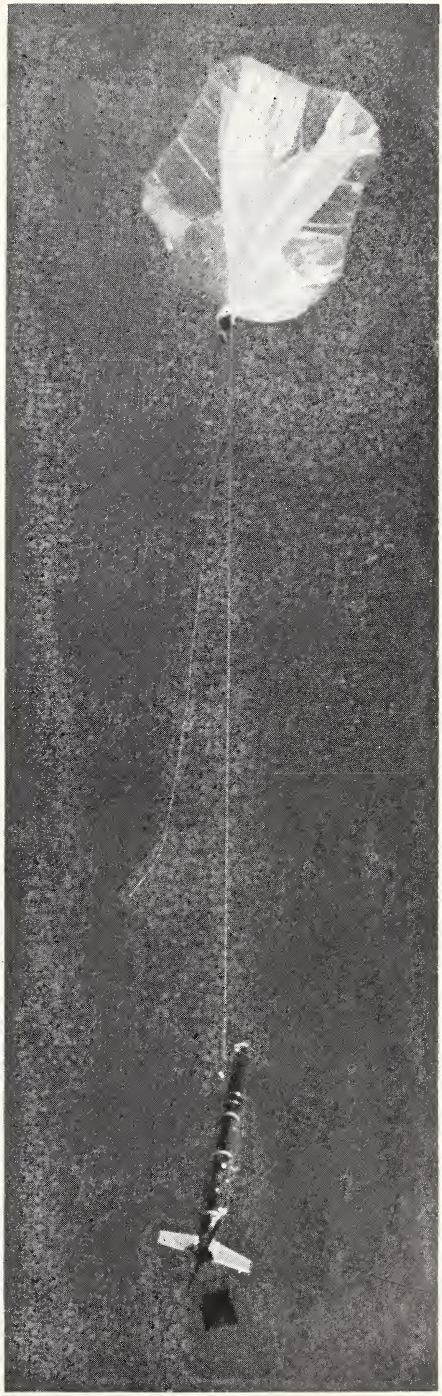
You know that air has weight. For instance, the air in an ordinary classroom may weigh more than 500 pounds, more weight than you can lift. And because air has weight, it has pressure.

There are always some small changes in air pressure at sea level. When we speak of an air pressure of 14.7 pounds per square inch (p. 148), we really are speaking of the average air pressure. Air pressure in any one place may go slightly above 14.7 pounds per square inch or slightly below this amount. Furthermore, air pressure becomes lower as we go into the upper air. What causes these changes?

Why Air Pressure Changes

It will help you to understand changes in pressure if you think of the air as a kind of seesaw. Suppose four boys sit on a seesaw. Two boys of the same weight sit on one end of it, and two boys of the same weight on the opposite end. The boys are placed at equal distances from the middle. If they sit still, they and the seesaw will not move because both ends of the seesaw weigh the same. Now suppose one of the boys gets off the seesaw. What will happen?

Think of the atmosphere as a kind of seesaw in perfect balance, with an equal number of molecules (having the same weight) in the air on opposite ends of the seesaw. Since there is equal weight of air, there is equal pressure. This is what happens in a dead calm. Now suppose something



U.S. NAVY

99 This skyhook balloon was carried by a rocket that rose 60 miles. Instruments in the rocket's nose reported data about the upper atmosphere. What use is such information?

were to take away a number of molecules of the air from one end of the seesaw. What would happen?

What do you suppose could lighten one end of this air seesaw? Remember the trip we took to the seashore. The air rose over the warm areas of the land and sank over the cooler places on the ocean. This unequal heating of the air is one of the causes of the change in air pressure which tips the air seesaw. Cold air is heavier and moves in to take the place of the warm air that rises. Cold air, therefore, has more pressure than an equal volume of warm air.

Another thing that can move the seesaw in the air is water vapor. Think of a large glass box of dry air at one temperature. A box of this dry air will have a higher pressure (will weigh more) than will another box of air of the same size in which there is a good deal of water vapor. Don't think of water vapor as steam. Water vapor cannot be seen because it is a gas. Steam is the name given to the heated water vapor which passes off as water boils. Let us see how water vapor helps change the weather.

WATER VAPOR IN THE AIR

When most people think of the weather, they do not think about air pressure or the movement of the atmosphere. They think of temperature changes (is it warm or cold?) and of clouds, rain, snow, sleet, or fair skies. They wonder most about weather changes that will be caused by the water vapor in the air.

Water takes a long time to cool and also to warm up. For this reason oceans, lakes, and large rivers play an important part in the daily weather. Cold air blowing across large bodies of water is warmed somewhat by the past summer's heat that is still in the water. On the other hand, in the summer, hot air passing over cold water is cooled when it gives up some of its heat to the cooler water. As a result, winters along the seacoast are usually warmer and the summers cooler than they are inland, because the water is near. This is usually true if the prevailing winds cross a wide body of water before reaching the land.

However, comfort does not depend upon temperature alone. Have you heard this remark, "It isn't the heat; it's the humidity"? What does this mean?

Humidity

You have, of course, noticed the dampness of the air when it is foggy or when it rains or snows. There is some moisture in the air at all times and at all places in the form of water vapor which no one can see. In fact, from 0.1 to 2.5% of the air may be water vapor. Water vapor, you will remember, is a gas.

The higher the temperature of the air, the more water vapor it can hold. The lower the temperature of the air, the less water vapor it can hold. Thus, when the temperature of the air drops suddenly, some of the water vapor in it changes to drops of water in the form of clouds, rain, or dew.

The amount of water vapor in the air is called the *humidity* of the air. High humidity may make you very uncomfortable. Your body is always giving off water through the skin and lungs. The heat of the body turns

this water into vapor; that is, the water evaporates. When liquid water turns into water vapor, we call the process *evaporation* (eh-vap-uh-RAY-shun). However, if the humidity is high, that is, if the air already has in it a good deal of water vapor, the water from your body cannot evaporate easily. As a result you may feel sticky and warm. Instead of evaporating, your body water stays on your skin and remains as drops of sweat.

Water to Water Vapor

Water, like air and all other substances, is made up of molecules which are always in motion. Molecules move faster the more they are heated. When any liquid is heated, some of these fast-moving molecules in the liquid move fast enough to escape into the air as vapor. When a heated molecule evaporates (escapes from a liquid) it takes a bit of heat with it. Thus, evaporation leaves the surface from which the liquid came cooler than it was before.

The evaporation of sweat helps to keep your body cool.

You can show this simply by wetting your hand and then waving it in the air. Notice how cool your hand feels. The evaporation of the water removes heat from your hand; to put it another way, the heat from your hand helps make the water evaporate.

The cooling effect of evaporation also explains why you feel cold when you stand around in a wet bathing suit on a windy day. Some of your body heat is lost as the water in your wet suit evaporates into water vapor.

Clouds

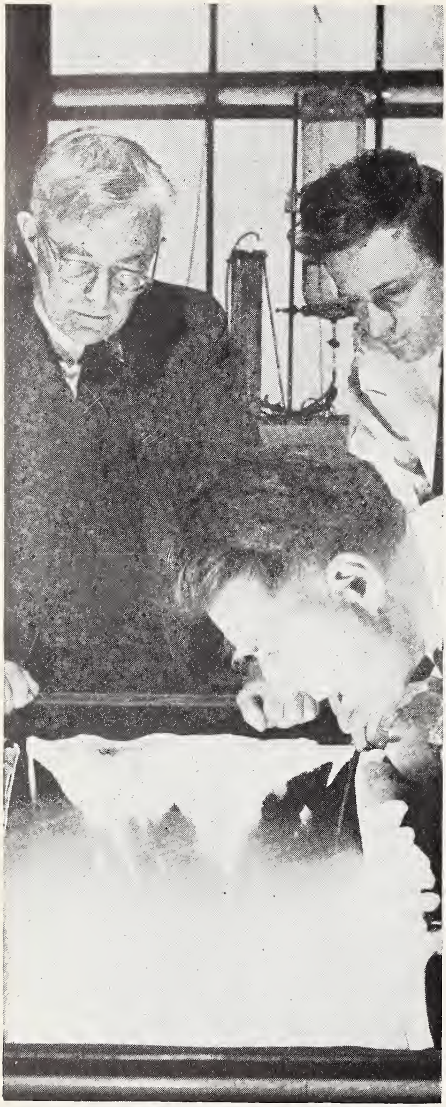
Although the water vapor in the air cannot be seen, it sometimes forms small droplets which can be seen. You then may see a cloud. Clouds are formed from water vapor. This usually happens when the air temperature falls, because cool air cannot hold as much water vapor as warmer air. Cooler air has less heat and therefore cannot keep water molecules moving fast enough to stay in the air as water vapor. So the water molecules form a cloud instead.

It is easy enough to see how a cloud may form. On a cold day have you ever made a cloud with your breath? Your breath has water vapor in it. The cold air outside your body cannot hold as much water vapor as the warm air inside your body. When your breath is cooled, the small cloud that forms is made up of millions of tiny droplets of water. Both the fog you see near the ground and the clouds you see high in the sky are made of these tiny droplets when warm moist air hits cooler air.

Rain, Snow, Sleet

When the drops of water in a cloud get big enough and heavy enough, they may fall to earth as rain. If the air is very cold, the drops of rain may freeze and form sleet. Hail is formed in a different way. This is explained in Chapter 11.

Snow is not formed as rain is. Remember that air gets colder the higher it rises (p. 210). As warm air full of water vapor rises from the earth, it is cooled, and the water vapor then forms clouds. (When water vapor again forms drops of water, we say the vapor *condenses*.) A



GENERAL ELECTRIC

100 Scientist Vincent J. Schaefer is shown blowing his breath into a home freezer. To make artificial snow fall, he will shave tiny particles of dry ice into the cloud you see. *Project:* If you have a home freezer, and your parents will let you, repeat this experiment.

cloud may be formed even at a temperature below 32° F., that is, below the point where water freezes. Such clouds are called *supercooled*. They are made up of supercooled drops of water (condensed water vapor) that do not form ice, even though they are below the freezing point of water. Often the high clouds in the upper air where the air is very cold are of this kind. Under certain conditions, they may change quickly into snowflakes. Dr. Vincent Schaefer of the General Electric Research Laboratories discovered a way to change a cloud of supercooled water droplets into snowflakes.

You can do this yourself simply by setting up a cold chamber, like the one shown in Fig. 100. Breathe into it, and a cloud will form. Then shave bits of dry ice into the cloud. You will soon see snow crystals appear. (*Warning:* Do not hold the dry ice in your bare hand.)

Scientific Weathermakers

The airplane makes it possible for man to treat clouds with dry ice and other things in order to make rain or snow. This is called *seeding*. Because it is so easy to seed clouds, some people expect that it can be used to prevent droughts (DROWTZ). A drought is a long period of time during which little or no rain falls and farm crops dry up.

The kind of weather we make depends upon the kind of clouds we seed and upon weather conditions nearby. If the conditions are nearly right for rain or snow, seeding may speed up the fall or make it fall on one area rather than another. A weathermaker needs to know all the conditions. A rain that is too heavy

may wash away land and ruin crops. Strong winds and hail may come with the rain and cause a disaster worse than the drought. A bolt of lightning may start a raging forest fire.

Weathermakers, however, are trying to find out more about weather changes and the best time to seed clouds. Experiments have been going on in many parts of the world. England, Australia, South Africa, Algeria, and Hawaii are among the places sending in reports.

What may be some of the uses of cloud seeding? It may be possible to get more snowfall on the sides of mountains so that there is a steady water supply from mountain streams. Another possibility is to keep ice from forming on the wings of airplanes. Supercooled ground fog near an airport may also be cleared away by seeding.

Scientists, as you can see, have been studying the *water cycle* (Fig. 101). The water cycle starts with the evaporation of water into water vapor. The water vapor then condenses and forms tiny droplets of water that make clouds. Finally, the water returns to the earth as rain, snow, hail, or sleet. Sooner or later, it will again evaporate. This process repeats and repeats. It is therefore called a cycle.

THE SUN'S ENERGY AS A WEATHERMAKER

As we have seen, the water cycle, differences in air temperature, differences in air pressure, and the amount of water vapor in the air are the causes of most weather changes. But these causes need a source of energy to set them in motion. The heat energy sent out by the sun does this. The sun is the most important of all the weathermakers.

Rays from the Sun

No doubt you have noticed that the weather changes a bit after nightfall and again about dawn. In Chapter 12 you will also learn why weather changes with the seasons. You may now realize that our weather depends on the sun more than any other single thing except the air.

The earth's blanket of air, the atmosphere, is clear enough to allow some rays from the sun to reach the earth. Dust, water vapor, and clouds in the atmosphere shield us from some of the rays, so that we are protected from the sun's full strength. If we lived on the moon, which has no atmosphere, we would have to wear special suits or live in caves to get this protection.

The rays from the sun that get through the atmosphere warm the earth. Soon after sundown this warmth would be lost were it not for the earth's atmosphere. This holds the heat on the earth much as a blanket holds your heat when you are in bed. The atmosphere helps the land and oceans to keep some of the heat they get from the sun during the daytime. This does not happen on the moon. There, as soon as night falls, the temperature of the land drops far below zero. On the dark side of the moon, which does not get the sun's rays, the temperature is thought to be almost $-459°$ F., which is as cold as anything can get.

The amount of heat the earth loses during the night depends upon the amount of water vapor and the size of the clouds that may be in the

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THE WATER CYCLE

101 Fog disappears as the droplets of water evaporate to form water vapor. When water vapor condenses, it forms a cloud (*top*). The cycle is completed when rain falls from the cloud.

atmosphere at the time. On clear, dry, cloudless nights more of the earth's heat is lost than on humid, cloudy nights. Thus on clear nights, soon after sundown, the earth's temperature and that of the air close to it fall rapidly. It is during nights like this that the heaviest dews form. The weather-wise have a saying like this:

Evening red and morning gray
Help the traveler on his way.

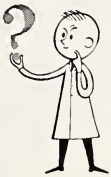
It is a true saying, for "evening red" means the air is clear and cloudless. The grayness of the early morning is caused by light clouds or haze that will evaporate soon after sunrise.

The opposite is also true. It goes:

Evening gray and morning red
Bring down rain upon his head.[1]

[1] A gray sky in the evening is caused by low clouds, which usually bring rain or snow. In the morning, a red sky is caused by many particles of moisture that may be a sign of rain coming soon.

To be able to tell what kind of weather is coming next, you need to know facts and figures. In the next chapter, you will find out how to get this information. You will start on the road to becoming a weather forecaster — that is, if you are interested in doing the work needed.



LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

doldrums	humidity	atmosphere
stratosphere	evaporation	troposphere
ionosphere		

1. the process of changing water to water vapor
2. the part of the atmosphere 10 to 50 miles above the earth
3. the region of the atmosphere above the stratosphere
4. a belt of calms near the equator
5. the amount of water vapor in the air
6. the lowest part of the atmosphere, where the weather changes which affect us take place
7. air which blankets the earth

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. As we stand on the earth we are surrounded by . . . which is always in motion.
2. One major cause of winds is the unequal . . . of the atmosphere. The other major cause of winds is the . . . of the earth.
3. Air pressure is the . . . of the air on each square inch of the earth's surface. At sea level, the pressure is about . . . pounds per square inch.
4. In a cupful of warm air there are . . . molecules than there are in a cupful of cold air.
5. Cold (or cooler) air will cause warm air to be pushed . . . .
6. As you climb up a mountain, the . . . of the air becomes less than at sea level.
7. The main changes of weather take place in the . . . part of the atmosphere.
8. Humidity means the amount of . . . in the air. When the humidity of the air is . . . , evaporation goes on more slowly.
9. The atmosphere and the clouds shield us from too much . . . .
10. The amount of heat lost by the earth is greatest on nights that are . . . .

GOING FURTHER

In the Laboratory and Field

1. Silica gel is a new chemical that is being used to fight humidity. As you know, in moist air iron rusts easily. To show how silica gel takes water vapor out of air, set up the experiment shown in Fig. 102. If your silica gel is dry, it will keep the iron from rusting.

2. *Heat and air pressure.* Does the heating of the air cause pressure changes? Drop a small piece of burning paper into a milk bottle. Place the palm of your hand over the mouth of the bottle the instant the flame goes out. Wait a full minute. Now raise your hand. Explain the result.

Put on Your Thinking Cap

1. Why are we just now beginning to learn more about the stratosphere?
2. Why is it that aviators who expect to live to a ripe old age make sure they are weather-wise?
3. Why may the atmosphere be called a blanket?
4. Why is our sun called the star that makes our weather?

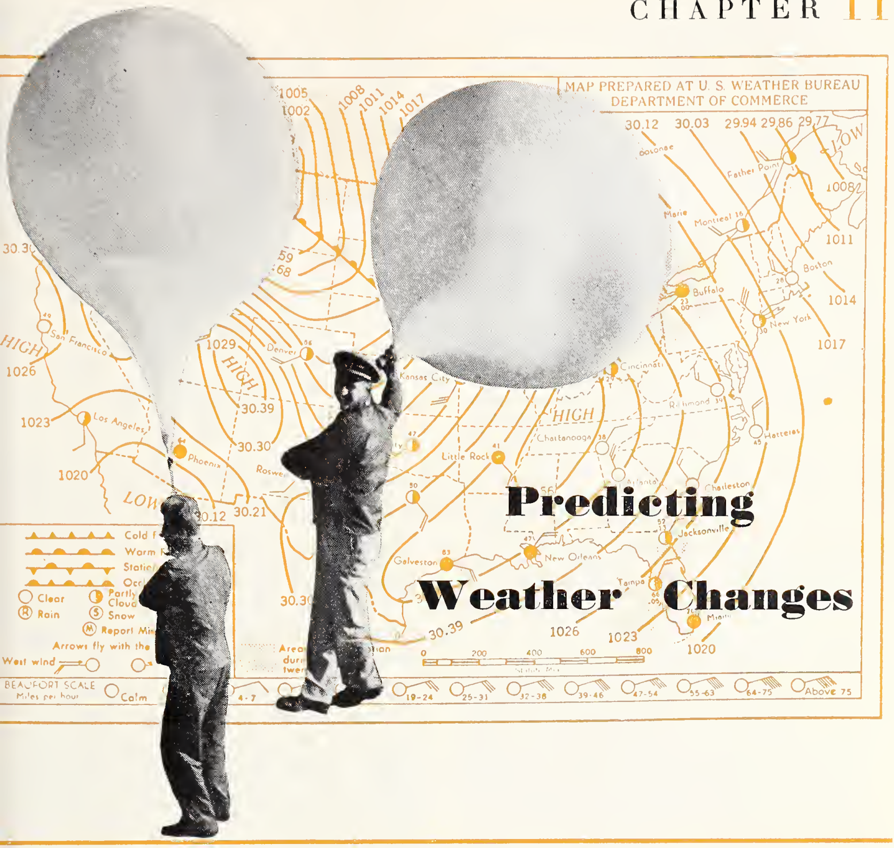
Adding to Your Library

1. *Exploring the Weather* by Roy A. Gallant, Garden City (Doubleday), 1957. Clever drawings make complex weather ideas easy to understand in this book.
2. *Everybody's Weather* by Joseph Gaer, Lippincott, Philadelphia, 1957.
3. *The True Book of Air Around Us* by Margaret Friskey, Childrens Press, 1953.
4. *Snow* by Thelma Harrington Bell, Viking, 1954.
5. *Weathercraft* by Athelstan F. Spilhaus, Viking, 1951.
6. *All About the Weather* by Ivan Ray Tannehill, Random, 1953. While this book tells a great deal about the weather, it is not written in technical language. Its author is a top man in the U.S. Weather Bureau.
7. *Our Changing Weather* by Carroll Lane Fenton and Mildred Adams Fenton, Doubleday, 1954. A well-illustrated, clearly written book.
8. *Everyday Weather and How It Works* by Herman Schneider, Whittlesey (McGraw), New York, 1951. This book tells how to build a weather station out of simple materials.

102 Silica gel is a substance that can take up great amounts of water vapor. By doing so it lowers the humidity in a closed room or jar. In this experiment, we see that silica gel is valuable in preventing rust.

CHAPTER 11

Predicting Weather Changes

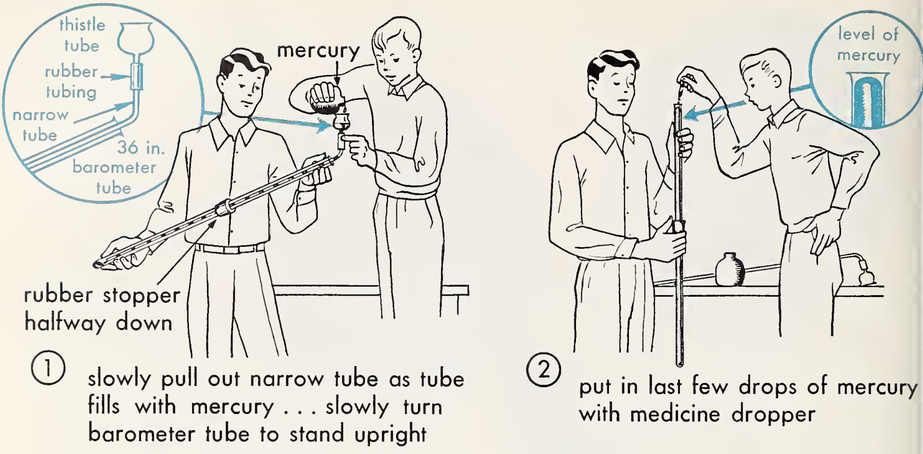


The balloons will go up, and they will be watched very carefully. What will they tell us about the weather? Understanding the work of weathermen will help you to make better use of their reports.

HAVE YOU NOTICED that almost everybody seems to think he can tell what tomorrow's weather will be? Often it amounts to saying, "I think it will be a nice day tomorrow, if it doesn't rain." On the other hand, there are sound ways of finding out what tomorrow's weather may be. Let us see what some of these ways are and how you can learn to use them.

The Amateur Weathermen

Have you ever heard of the group of people called the Amateur Weathermen of America? In this group are people of all ages, even boys and girls, who make their own weather observations and report them to the United States Weather Bureau. They know what they are doing and why they



103 *Project:* Make a mercury barometer by following the four steps shown here. Why must the mercury be poured carefully? What is the purpose of the rubber stopper?

are doing it. If you would like to be a Co-operative Observer, this chapter will give you a start.

The U.S. Weather Bureau

The secret of success in predicting the weather is co-operation. The weather predictions of the United States Weather Bureau (Fig. 109) are correct 80 to 90% of the time because information comes from hundreds of observers. They are scattered over the widest possible area, including Alaska and Greenland. One post is within 150 miles of the North Pole.

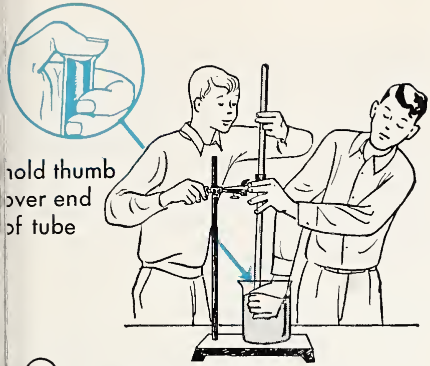
Before you try to read information from a weather map, you should know how weather observers get their information and how weather instruments work.

MEASURING AIR TEMPERATURE AND PRESSURE

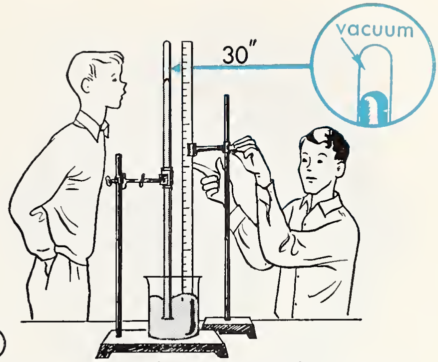
The most common weather instrument is a thermometer. Many people have one inside their house and one outside near a window so that they can read it without going outdoors on a cold day. Most thermometers are glass tubes with a bulb at one end filled with a liquid such as mercury or red-colored alcohol. As the temperature changes, the length of the column of liquid in the tube rises or falls. You read the thermometer in degrees from a scale marked on the tube or alongside it. With a thermometer of this kind, your reading is the temperature of the moment. You do not know whether the air has been hotter or colder an hour earlier, let us say. To find this out, other kinds of thermometers are used.

Kinds of Thermometers

Weathermen wish to know the temperature over a 24-hour period, or shorter periods of time. For this they use a *maximum-minimum thermometer.* A maximum-minimum thermometer has a tiny metal marker that the thermometer leaves at the lowest tem-



③ turn tube upside down in beaker of mercury ... fix tube to ring stand



④ attach yardstick to ring stand ... measure height of mercury by reading from top of mercury in beaker to top of mercury in barometer tube

Caution: Do not put your hand into the mercury if you have a cut on your skin. Scrub your hands before touching food. Inside the human body, mercury is a deadly poison.

perature, and another that it leaves at the highest temperature, during the particular period of time. The present level of the liquid, of course, gives the present temperature. After the reading is made and put down in a record book, the markers are reset so that the highs and lows of temperature for the next period will be shown. The weatherman keeps his maximum-minimum thermometer in a little outdoor box to protect it from damage and also to shield it from the direct rays of the sun. If you want to understand why it must be shielded, set up two thermometers, one in the shade and one in the sun's rays, and notice how different the readings are.

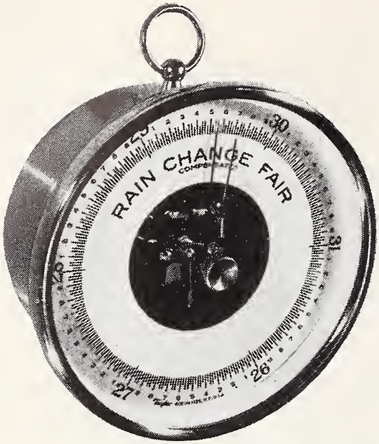
A *thermograph* (THER-moh-graf) gives even more information than a maximum-minimum thermometer, for it gives the weatherman a record of every temperature change for every minute of the period he is studying. As its name suggests, the record of temperature on a thermograph is a line drawn on a piece of paper. In one type of thermograph, the graph paper is around a drum that looks like a large tin can. This drum is turned by a clock.

No matter what kind of thermometer we use, air temperature is measured in degrees Fahrenheit.

Water and Mercury Barometers

Weathermen also want to know the air pressure. Air pressure is sometimes called *barometric* (bair-oh-MET-rik) pressure, because the amount of air pressure is measured with a *barometer* (buh-ROM-uh-ter) or a *barograph* (BAIR-uh-graf).

An Italian scientist named Torricelli (tor-uh-CHEL-ee) (1608–1647), a pupil of Galileo, made the first barometer, in 1643. His barometer used mercury. To this day some of the best barometers use mercury. You can make a simple type of mercury barometer, like the one shown in Fig. 103. Notice that it uses a tube about 3 feet long in which the mercury stands at a height of about 30 inches.



TAYLOR INSTRUMENT CO.

104 An aneroid barometer measures changes in air pressure. Aneroid barometers do not contain mercury. The pressure of air acts directly on the box, pushing it in or out a bit. The needle shows this pressure.

Torricelli discovered that the pressure of the air at sea level can hold up this column of mercury by pressure on the liquid in the dish (Fig. 103). When the air pressure becomes less, the pressure on the mercury becomes less, and the mercury drops a bit. When the air pressure becomes greater, the pressure on the mercury column is greater, and it rises a bit higher in the tube. A falling barometer, on the other hand, means lower air pressure.

Mercury weighs 13.6 times as much as water, so you see why water is not used in barometers. Aside from the fact that water would freeze in the winter, you would need a tube about 34 feet high for a water barometer. Otto von Guericke (GAY-ruh-keh) (1602–1686), the famous mayor of Magdeburg, Germany, actually made a water barometer. But the superstitious townspeople made him take it down. They noticed that every time the water level went down it rained or stormed. Since they did not know the facts, they blamed the bad weather on the barometer. Of course, they overlooked the fact that there were just as many storms after the barometer was removed as during its use.

Other Barometers

You may know of another kind of barometer, called an *aneroid* (AN-er-oid) barometer. The main part of an aneroid barometer is a small, flexible metal box. Most of the air has been removed from the box. Changes in air pressure cause a pointer to move around a dial.

Since part of the air inside the box has been taken out, the pressure of the air left *inside* is less than the air pressure *outside* the box. The top and bottom of the box, therefore, are pressed together a certain amount. If the pressure of air on the outside of the box becomes less, the top of the box is pushed out a bit by the air left inside. If the outside air pressure becomes greater, the top of the box is pushed in slightly. Whenever the top of the box moves, the pointer moves over the dial, which is shown clearly in Fig. 104.

The invention of the aneroid barometer made it possible to do away with the three-foot tube of liquid mercury which is used in a Torricelli barometer. For this reason an aneroid barometer is much lighter in weight, less expensive, and easier to carry. There is also no danger of spilling mercury.

An aneroid barometer is often used for measuring altitude. When so used, it is called an altimeter (al-TIM-uh-ter). You remember that when we

go up in the atmosphere, the pressure of the air becomes less. If we were to carry a heavy mercury barometer to the top of a high mountain (and this has been done), we would find that the level of the mercury would drop about one-tenth of an inch for every 90 feet the barometer is carried upward. Thus a barometer can be used to measure our altitude above sea level. Information about altitude is important to airplane pilots. Aneroid barometers are used as altimeters in airplanes.

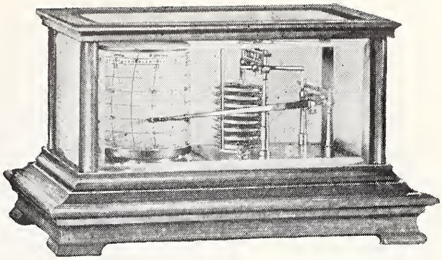
Normal Air Pressure

Sometimes the same thing has many different names. So it is with air pressure. Normal air pressure (at sea level) may be described or measured in seven ways:

NORMAL AIR PRESSURE =	29.92 inches of mercury
	76 cm. of mercury*
	760 mm. of mercury†
	33.9 feet of water
	1 atmosphere
	14.7 pounds per square inch
	1013.25 millibars‡

As you see, all these figures mean the same thing, normal air pressure. The description of air pressure now favored by the U.S. Weather Bureau is the last one in the list. On a barometer scale, 0.1 of an inch of mercury measures the same air pressure as 3.4 millibars. You do not need to worry too much about the arithmetic of changing inches of mercury into millibars. Every weather map gives both figures because many people who use the weather maps like the older method better. For the air pressures you are most likely to use, see the bottom half of the table given here.

* 1 inch = 2.54 centimeters (cm.)
† 1 cm. = 10 millimeters (mm.)
‡ Based on 1 inch at 32° F. = 33.86 millibars



TAYLOR INSTRUMENT CO.

105 A barograph records the changes in air pressure throughout an entire day. The arm you see writes on the paper as the drum turns.

Range of Pressures

Mercury in Column Inches	*Millibars*
29.0	982.05
29.1	985.44
29.2	988.83
29.3	992.21
29.4	995.60
29.5	998.99
29.6	1002.37
29.7	1005.76
29.8	1009.14
29.9	1012.53
30.0	1015.92
30.1	1019.30
30.2	1022.69
30.3	1026.08
30.4	1029.46
30.5	1032.85

It may surprise you to learn that the barometer readings change very slightly in any one place. Over a

period of 66 years, the U.S. Weather Bureau in Philadelphia recorded a total change of only 2.48 inches between its record high of 31.02 inches and its record low of 28.54 inches. Small changes can mean a lot and be very important.

The Falling Barometer

Have you ever heard the statement: "The barometer is falling; a storm is on the way"? When the level of the mercury in a barometer goes down, the barometer is said to be falling. This is a sign that the air pressure in the area is becoming less. A drop of even 1 inch in a period of 24 hours is unusual and marks the rapid approach of a violent storm. Such a storm is called a "low-pressure area," or simply a "low." Remember that one main cause of lowered air pressure is a rise in temperature (see p. 212).

If there is a high amount of water vapor in the air, air pressure is lowered. If you were to weigh a box of dry air, you would find that it has a certain weight. If you were to fill the same box with water vapor, under the same conditions, you would find that the box full of water vapor weighs less than the box full of dry air. Therefore, the box with a high amount of water vapor has a lower pressure than the one with dry air.

Water vapor is not made up of the tiny drops of water in the air which can be seen as clouds. Water vapor, you remember, is a gas that cannot be seen. A given amount of air plus water vapor weighs less than the same amount of air alone. This is so because molecules of water vapor weigh less than the molecules of the other gases that make up the air.

What will happen when a barometer is placed in warm air which holds much water vapor? The column of mercury in the mercury barometer will fall, or the needle in the aneroid barometer will show a lower pressure. Why? Warm air which holds much water vapor does not weigh as much as an equal volume of cold, dry air. Since it has less weight, it does not press as much on a column of mercury or on an aneroid barometer. Thus warm, moist air has a lower pressure than cool, dry air.

Since water vapor may condense and fall as rain, a falling barometer may mean that rain is coming. Rain does not always come because sometimes conditions are not right to cause rain to fall. For the opposite reason, a rising barometer is taken as a sign of dry, fair weather.

MEASURING RAINFALL

Co-operative weather observers must make a report of temperature changes and *precipitation* (preh-sip-ih-TAY-shun) to the U.S. Weather Bureau.[1] They may report on changes in air pressure if they wish. Precipitation means any form of moisture that falls from the air to the earth. Rain, snow, and hail are forms of precipitation. Dew is not precipitation because it does not form in the air and fall to the ground. Dew forms upon objects on or near the ground.

In the United States, rainfall and snowfall are measured in inches (Fig. 106). The average yearly pre-

[1] The U.S. Weather Bureau supplies co-operative observers with a thermometer for measuring the air temperature. It also supplies a rain gauge for measuring precipitation. Many amateur weathermen buy their own instruments and gauges.

106 Rainfall is measured by the number of inches of water that collect in a cylinder of the kind shown in use here. Measurements are made before the water collected has a chance to evaporate. *Project:* Make a rain gauge and keep a record of the daily rainfall.

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cipitation for Washington, D.C., is 42.16 inches. A day during which 0.01 inches or more rain falls is called a rainy day. Most people do not need a rain gauge to show them that a particular day is rainy. However, a record of the rainfall during a season may be very important. It shows the amount of water that is available for wells and reservoirs and for agriculture. A record of rainfall also tells when to take steps against drought. A drought, as you remember, is a long period during which little or no rain falls, such as the summer drought of 1953. What is the average yearly precipitation in the part of the country where you live?

If you want to measure precipitation with a rain gauge, place it where it will receive a normal amount of precipitation. If it is placed too close to a wall, it may not catch the full amount of rain that actually falls in the open places. To read the smaller rain gauges, a ruler is put down into the gauge. The water leaves a wet mark on the ruler, just as the oil in an automobile engine leaves its mark on the oil gauge. If you are using a rain gauge, read it as soon as the rain stops, or else some of the water collected in the gauge may evaporate and your reading will not be correct.[1]

MEASURING RELATIVE HUMIDITY

Even before rain falls, you can get an idea of the amount of water vapor in the air by measuring the *relative humidity.* The relative humidity is a measure of the amount of water vapor in the air compared to the

[1] Snow will melt in the gauge and can be measured in that way.

amount of water vapor the air can hold at a certain temperature.

Relative humidity is always measured in percentages. When the air is holding every bit of moisture it can hold, the relative humidity is, of course, 100%. When the air is 100% humid, the slightest drop in temperature may cause precipitation. A relative humidity of 90% or more often means that we may soon have some form of precipitation.

A relative humidity of 50% means that the air is holding just half as much water vapor as it can hold if the temperature does not change.

Does water vapor ever come out of the air? You can show there is water in air by doing this. Put ice in a metal cup. As the ice lowers the temperature of the cup, the cup in turn lowers the temperature of the air around it. At this lower temperature, the air cannot hold as much water vapor as it did before. The air touching the cup quickly reaches a relative humidity of 100%. Further cooling of the air causes some of its water vapor to form (condense) on the sides of the cup as dew. Where are you likely to find dew forming inside your house?

Everyone has seen dew on grass, stones, and other objects on the ground. Dew is formed when warm air, containing enough water vapor, comes in contact with the cool earth. What happens is like the forming of drops of water on the sides of the ice-filled cup. Why doesn't dew usually form during the day? During the day the earth is usually as warm as the air or warmer. Therefore, the temperature of the air is not lowered by coming in contact with the earth, and the water vapor does not form dew.

You can use a simple but very rough method to find out whether the air is very humid. Water vapor changes the color of a chemical known as cobalt chloride. Cobalt chloride is blue when it is dry; it turns pink or red when it has taken up water vapor from the air.

Try to make a simple instrument to measure the water vapor in the air by using cobalt chloride solution. A piece of filter paper will take up cobalt chloride. Let it dry. What color will the filter paper be when the air is dry? When it is moist?

Making a Weather Instrument

The cobalt chloride method described above is not accurate enough. An accurate instrument used to measure humidity is called a *psychrometer* (sy-KROM-uh-ter) (Fig. 107). It is easy enough to make one of your own.

A psychrometer is made from two thermometers which are exactly alike. You will also need the chart shown in Table 7 and a small wad of cotton. Pull out the strands of the cotton until it is thin enough to slip under the bulb of one of the thermometers. Then wrap it all around the bulb. Now moisten the cotton thoroughly with water. Fan both bulbs. Notice that the temperature shown on the wet-bulb thermometer is lower than that on the dry-bulb thermometer. Continue to fan until there is no further drop in temperature. Read the temperatures on both thermometers and turn to Table 7. Look down the column in the table giving the dry-bulb temperature you have read. Put a ruler on it.

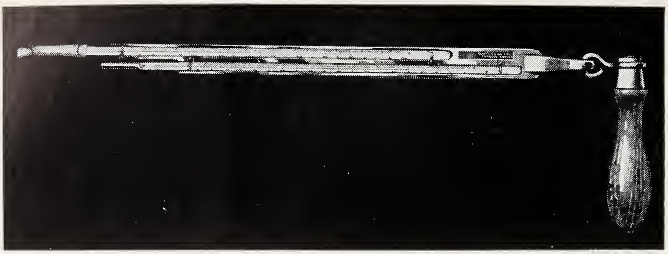
TABLE 7 Relative Humidity Chart

TEMPERATURE OF DRY BULB

TEMPERATURE OF WET BULB

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	
41	7	4	2																		41
42	10	8	6	4	2																42
43	14	12	10	7	5	3	2														43
44	18	16	13	11	9	7	5	3	1												44
45	22	20	17	15	12	10	8	6	5	3	1										45
46	27	24	21	18	16	14	12	10	8	6	4	3	1								46
47	31	28	25	22	20	17	15	13	11	9	7	6	4	3	1						47
48	35	32	29	26	24	21	19	16	14	12	10	9	7	5	4	3	1				48
49	40	36	33	30	27	25	22	20	18	15	13	12	10	8	7	5	4	3	1		49
50	44	41	37	34	31	29	26	23	21	19	17	15	13	11	9	8	6	5	4	3	50
51	49	45	42	38	35	32	30	25	24	22	20	18	16	14	12	11	9	8	6	5	51
52	54	50	46	43	39	36	33	31	28	25	23	21	19	17	15	13	12	10	9	7	52
53	58	54	50	47	44	40	37	34	32	29	27	24	22	20	18	16	14	13	11	10	53
54	63	59	55	51	48	44	41	38	35	33	30	28	25	23	21	19	17	16	14	12	54
55	68	64	60	56	52	48	45	42	39	36	33	31	29	26	24	22	20	18	17	15	55
56	73	69	64	60	56	53	49	46	43	40	37	34	32	29	27	25	23	21	19	18	56
57	78	74	69	65	61	57	53	50	47	44	41	38	35	33	30	28	26	24	22	20	57
58	84	79	74	70	66	61	58	54	51	48	45	42	39	36	34	31	29	27	25	23	58
59	89	84	79	74	70	66	62	58	55	51	48	45	42	39	37	34	32	30	28	26	59
60	94	89	84	79	75	71	66	62	59	55	52	49	46	43	40	38	35	33	31	29	60
61	100	94	89	84	80	75	71	67	63	59	56	53	50	47	44	41	39	36	34	32	61
62		100	95	90	85	80	75	71	67	64	60	57	53	50	47	44	42	39	37	35	62
63			100	95	90	85	80	76	72	68	64	61	57	54	51	48	45	43	40	38	63
64				100	95	90	85	80	76	72	68	65	61	58	54	51	48	46	43	41	64
65					100	95	90	85	81	77	72	69	65	61	58	55	52	49	46	44	65
66						100	95	90	85	81	77	73	69	65	62	59	56	53	50	47	66
67							100	95	90	86	81	77	73	69	66	62	59	56	53	50	67
68								100	95	90	86	82	78	74	70	66	63	60	57	54	68
69									100	95	90	86	82	78	74	70	67	63	60	57	69
70										100	95	91	86	82	78	74	71	67	64	61	70
71											100	95	91	86	82	78	74	71	68	64	71
72												100	95	91	86	82	79	75	71	68	72
73													100	95	91	87	83	79	75	72	73
74														100	96	91	87	83	79	75	74
75															100	96	91	87	83	79	75
76																100	96	91	87	83	76
77																	100	96	91	87	77
78																		100	96	91	78
79																			100	96	79
80																				100	80
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	

Suppose the "dry" thermometer (on your psychrometer) read 72° F., the "wet" thermometer 63° F. Then the relative humidity would be 61% (as above). The activity on the opposite page tells you how to use this chart. *Project:* Try keeping a relative humidity record for several weeks.



TAYLOR INSTRUMENT CO.

107 This is a sling psychrometer. Holding it by the handle, you sling it around your head to evaporate the moisture on the wet-bulb thermometer. This is easier than fanning the wet bulb.

Then look across the line giving the temperature of the wet-bulb thermometer. The number in the box where the column and the line meet is the percentage of relative humidity. An example is worked out for you under Table 7, and the result has a circle around it.

MEASURING WINDS

With the exception of the rain gauge and the cobalt chloride indicator, the instruments we have studied so far are delicate ones made for use indoors or under protecting boxes. The measurement of wind direction and wind speed needs well-built instruments, like the weather vane. It is not unusual for an amateur weatherman to discover that his weather vane has "gone with the wind" if it has not been well made and carefully fastened. Wires are shown holding down the weatherman's house, as well as his instruments, on p. 204.

Measuring Wind Direction

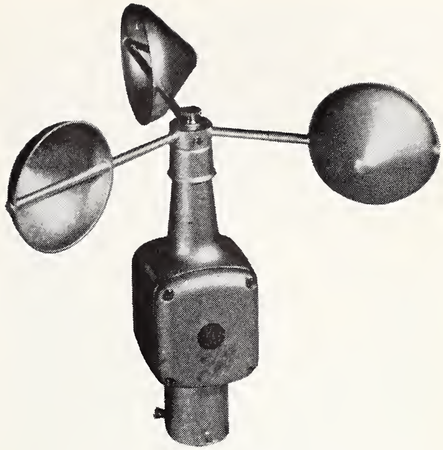
A weather vane is so familiar an object that it does not need to be described here. You have probably seen dozens of weather vanes turning first one way and then another, as the wind direction changes. Sometimes there are the letters N, E, S, W attached to the pole of the weather vane so that you can tell at a glance which direction of the compass the vane is pointing toward. Even so, some people do not read the message of the weather vane correctly. Here is a hint: flags, smoke, and clouds are blown *with the wind.* The pointer heads into the wind and shows us the direction from which the wind is blowing. This is the way we name winds, too — according to the direction *from* which they blow. A north wind is one that blows *from* the north. Be careful, though, when you look at a weather map.

Admiral Beaufort's Wind Arrows

The arrows that show wind direction (called Beaufort arrows) on the weather map fly *with* the wind, with only the tail feathers showing (Fig. 109). Beaufort arrows are strange things which do not look very much like real arrows. On p. 229 you see a whole column of them. Each is a circle and a line to which other lines

are fastened, some long, some short. These last are the feathers of the arrow, but they are not put there for decoration. Each line and its length shows a different wind speed. The arrows are the weatherman's code for a system of measuring wind speeds. This system was invented about 1805 by Sir Francis Beaufort.

The speed of the wind is measured by an *anemometer* (an-uh-MOM-uh-ter) (Fig. 108). There are several forms, but the most common kind of anemometer has three or four cups attached to short metal bars connected to a shaft. The wind, striking the cups, makes the shaft turn. As the shaft turns, it sets a speedometer (spee-DOM-eh-ter) in motion. This speedometer is read in miles per hour just as you read the speedometer on an automobile.

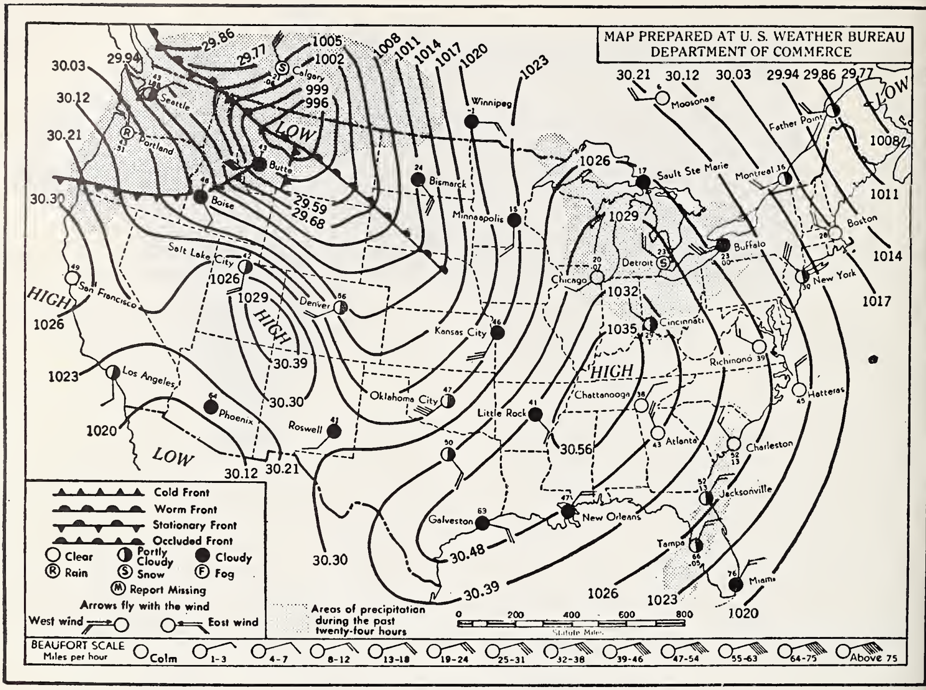


JULIEN P. FRIEZ AND SONS

108 A cup-type anemometer turns, no matter from what direction the wind is blowing. Its speed of turning measures the speed of the wind in miles per hour. *Project:* With your teacher's help organize a club of co-operative weather observers.

TABLE 8 The Beaufort Wind Scale

Scale Number	*Weather Description*	*Miles per Hour*	*Effects of the Wind*	*Beaufort Symbol*
0	Calm	0–1	Smoke rises straight up.	
1	Light air	2–3	Smoke shows wind direction.	
2	Slight breeze	4–7	Weather vanes turn, flags flap.	
3	Gentle breeze	8–12	Flags blow straight out.	
4	Moderate breeze	13–18	Dust clouds rise.	
5	Fresh breeze	19–24	Small trees bend, rivers and lakes don whitecaps.	
6	Strong breeze	25–31	Umbrellas turn inside out.	
7	High wind	32–38	You have to lean to walk.	
8	Gale	39–46	Branches break off trees.	
9	Strong gale	47–54	Shingles are torn off roofs.	
10	Whole gale	55–63	Trees topple, telephone wire and poles need repair.	
11	Storm	64–72	Damage is widespread.	
12	Hurricane	73–82	If you're alive, you are a survivor of a disaster.	



109 A weather map shows weather conditions shortly before the map was made. In our country, weather changes usually move toward the northeast. To predict weather coming your way, study the conditions west or southwest of where you live. *Project:* Using a daily weather map, make weather predictions and compare them with radio forecasts.

Upper-Air Weather Facts

Important as they are, the measurements of weather conditions in the lower part of the atmosphere do not give us all the information needed for good weather reports and predictions. Weather science has really gone "upstairs." Upper-air temperature, upper-air pressure, upper-air humidity, upper-air wind speed and

U.S. AIR FORCE

110 Winds aloft often blow at different speeds and in different directions than winds near the ground. By watching the flight of a pilot balloon with the device you see (called a theodolite), these men will learn much about the weather conditions of the upper air.

direction, and cloud study are needed for making the best weather predictions.

Special instruments are used to find out the temperature, pressure, and humidity of the upper air. These instruments are built into a lightweight radio broadcasting set known as a *radiosonde* (RAY-dee-oh-sond) (Fig. 111). The radiosonde is carried up into the air by a big balloon which, when filled with hydrogen gas, is about three feet in diameter (Fig. 111). Below the balloon is a small parachute. And below that is the radiosonde, which is about as big as a large carton of soap flakes. But it has in it a tiny short-wave radio set, a small aneroid barometer, an electric thermometer, a special psychrometer, a signal switchboard, and dry-cell batteries. The balloon rises until it gets into the thin upper air. As it rises, the outside air pressure becomes less. The hydrogen gas inside the balloon expands the balloon more and more until finally the balloon bursts. As the radiosonde starts to fall toward the earth, the parachute opens and lowers it to the earth gently. The finder returns the radiosonde to the U.S. Weather Bureau by mail (according to instructions printed on the outside of the box). If you ever find one of these boxes, be sure to mail it back promptly.

Sometimes a pilot balloon without a radiosonde is sent up. Until it becomes lost in the clouds, its path is followed by an observer who watches it through a *theodolite* (thee-OD-oh-lite) (Fig. 110). A theodolite is a telescopic range finder with which the speed and direction of the balloon may be tracked. Sometimes a balloon is tracked by radar. Sometimes the radar alone is used to get information about conditions in the upper air. Some of these balloons have been mistaken for flying saucers.

U.S. NAVY

111 Finding out what the weather is like "upstairs" in the upper air is an important part of the work of our armed forces. The balloon about to be released will carry a radiosonde aloft many thousand feet.

There are times also when weathermen go up into the air in high-flying planes to get information about weather conditions in the upper air.

CLOUDS AND FRONTS

We are fortunate in having all these sources of information about the weather in the upper air, but we do not have to wait until the facts are sent to us by the U.S. Weather Bureau. We can get some pretty important information about the weather just by looking up at the clouds.

For thousands of years, men have watched the changing sky and learned to know what kind of weather to expect. You will find it a great help to be able to know the different kinds of clouds — their shape, altitude, speed, and direction of travel. It is much easier than spotting airplanes, a skill so many of you have mastered.

Kinds of Clouds

When you study a cloud, follow two steps to find out what kind of cloud it is. First, note its size and shape, which is called its formation. Second, guess how high it is. Weathermen have an instrument to measure the height of clouds, but you can often make a fair guess because clouds of certain types are found at certain heights.

There are three main types of clouds (Fig. 112): *stratus* (STRAY-tus), *cumulus* (KYOOM-yoo-lus), and *cirrus* (SIH-rus). A stratus cloud covers the entire sky or a very large part of it with a flat sheet or layer so that you cannot see the blue of the sky if you are under this cloud. A cumulus cloud is shaped like a cauliflower or like great heaps of fluffy wool or cotton. A cirrus cloud is commonly known as "mare's tail" or "witch's broom"; it is high and white. The names of these clouds are easy to learn, especially if you can remember their original Latin meanings: *stratus* means "in layers"; *cumulus* means "a heap"; *cirrus* means "hairlike curls."[1]

These cloud formations usually appear at certain elevations. Cirrus clouds are never found low in the sky. They form at levels from 20,000 to 40,000 feet. Stratus clouds, however, form from the ground level, where they are called *fog* (Fig. 112), to about 6,000 feet. Cirrus clouds in layers (cirro-stratus, since *stratus* means "layers") may be found at 27,000 to 30,000 feet. Cirro-stratus clouds are easy to recognize at night because they form a ring of light or halo around the moon.

Unlike stratus clouds of different kinds which form in thin layers at various levels, cumulus clouds may reach upward from perhaps 4,500 feet to a height of 10,000 feet or more. Among these are the familiar anvil-shaped thunderheads. They appear before a thunderstorm and warn us of its coming. No matter where you are — in a canoe, sailboat, airplane, or playing in a meadow — always heed the warning of the thunderhead cloud.

Of course, there are many other kinds of clouds, but unless you intend to become a real weatherman, they need not concern you. If you are interested, you can get an illustrated book or chart describing every cloud form, just by writing to the

[1] To these three names may be added several prefixes, three of which you might want to know. They are: *alto*, meaning "high"; *fracto*, meaning "broken"; and *nimbus*, meaning "rain." Thus an alto-stratus cloud is a high stratus cloud. A fracto-cumulus is a broken mass of cumulus clouds. A nimbo-stratus cloud is a dark rain cloud, and a cumulo-nimbus is a thunderhead.

1 cirrus
"mare's tails"
over 30,000 feet

2 cirro-stratus
(like a thin veil)
causes a halo around moon

3 cirro-cumulus
(like rippled sand)
over 20,000 feet

4 alto-stratus
(like a thick veil)
about 19,000 feet

5 alto-cumulus
(like a herd of sheep)
over 12,000 feet

6 cumulo-nimbus
"thunderhead"
lowest level 5,000 feet

7 fractus or "scud"
(broken clouds)

8 cumulus
dome-shaped heaps
4,000 feet and over

9 nimbo-stratus
heavy rain clouds
about 3,000 feet

10 stratus
light rain clouds
1,800 feet

11 fog and haze
near the ground
"ceiling zero"

 If you watch the clouds very long, you will see all the types shown here. With experience you can learn to predict weather from cloud types. *Project:* Why not make a study of clouds? Keep a record for two weeks of the kinds you see each day and the weather for that day. Then, for two weeks, try to predict the weather. How nearly right were you?

U.S. Weather Bureau in Washington, D.C.

Cloud formations are of the greatest importance to persons who make weather predictions or fly airplanes. Clouds tell us when changes in the weather are beginning to take place. Their shape, size, altitude, and speed give us evidence of the weather aloft. The real importance of many cloud types is that they mark the presence of a cold or warm air *front* and tell us what kind of *air mass* is coming our way.

WEATHER FRONTS AND AIR MASSES

An air mass has three dimensions, a familiar term now that 3-D movies are here. It has *length*, *width*, and *height* (Fig. 113). Within any mass of air, the temperature, pressure at sea level, and humidity are about the same throughout. Thus if an air mass stays in one place for a while, the weather may remain hot, cold, dry, or humid, depending upon what kind of air mass it is. The air masses that come and go across the United States are of four main types.

An air mass is named for the region from which it comes. Ours are: *Polar Continental* (cP), *Polar Maritime* (mP), *Tropical Continental* (cT), and *Tropical Maritime* (mT). See Fig. 113.

Polar air masses come from the North or South Poles. Tropical air masses start near the equator. A Continental air mass comes from inland, and Maritime air masses, of course, come from over the sea.

A Polar Continental air mass is one that starts out from the north central part of Canada. A Polar Maritime air mass may come from the North Pacific or the North Atlantic. As you may have guessed, a *polar mass* is apt to bring us *cool weather*, and a *tropical air mass*, *warm weather*.

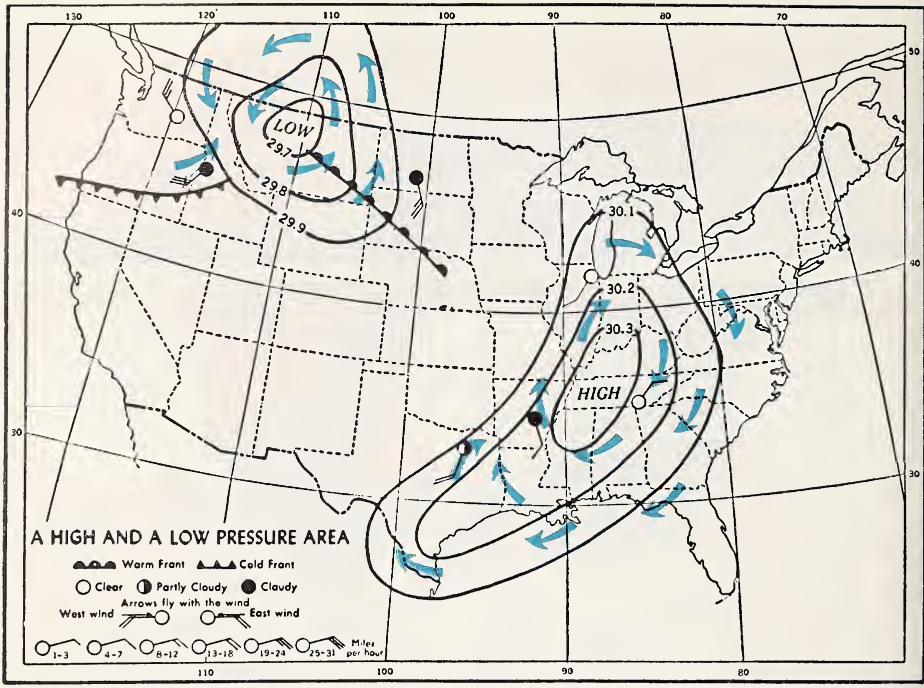
Whenever one kind of air mass meets an air mass of another type, a *front* is formed. The front is the boundary line of the two air masses. Along the front, clouds form and rain falls, if conditions are right. The type of front and the type of weather changes that happen along it depend upon the kinds of air masses that meet and how they meet. The two most common types of weather fronts are the warm front and the cold front (Fig. 113).

Weather Changes Along a Warm Front

A warm front is the boundary line between two air masses of different temperatures when the warmer air mass is *advancing*. If the colder air mass were advancing, we would call it a cold front. This boundary or front may be 1,000 miles or more long across the country, and 500 to 600 miles wide. It may slope upward from the ground to a height of about six miles.

The warm front is marked by the clouds that form along it. As the cool air of one mass mixes with the warmer air of the other, the water vapor in the warmer air condenses and forms clouds (as if the warm air struck a cold surface). At the highest level of the warm front, cirrus clouds form. As the front advances, the bottom level of the cloud ceiling drops and larger clouds appear. At last come the low-level (1,000 to 3,000 feet) stratus clouds from which rain falls.

113 Air masses from the north polar region and from the tropics bring us the weather conditions we experience in the United States. Where these air masses meet, fronts form. From the diagrams can you tell the differences between cold and warm fronts?



114 Winds whirl counterclockwise around a *low;* clockwise around a *high;* and from the center of a *high* toward the center of a *low*. Meanwhile the centers of the *highs* and *lows* move from west to east.

Other changes mark the advance of a warm front. The barometer drops, and an area of low air pressure called a *cyclone* forms. Remember that *cyclone* here means only an area of low air pressure. In a cyclone in the Northern Hemisphere, winds blow in a large counterclockwise circle (opposite to the direction the hands of a clock turn). The winds spiral slowly in toward the center of the *low* (Fig. 114). Sometimes wind speeds range from light (at outer edge) to stronger gale force (near center), and the area covered is 500 to 2,000 miles in diameter. Then we call the cyclone a *storm*. It is then that storm warnings are put up to warn people. Of course, the flags may go up to warn against something even worse, a *hurricane*. In Fig. 115 you see just such a signal. Storms and hurricanes are both cyclones.

Hurricane warnings are posted when a *typhoon* or *tropical cyclone* is on its way. A tropical cyclone is a violent type of cyclone. It covers a circular area, from 25 to 600 miles in diameter. In the beginning, at least, it has no fronts associated with it. During a hurricane the wind blows at 75 to 150 miles per hour.

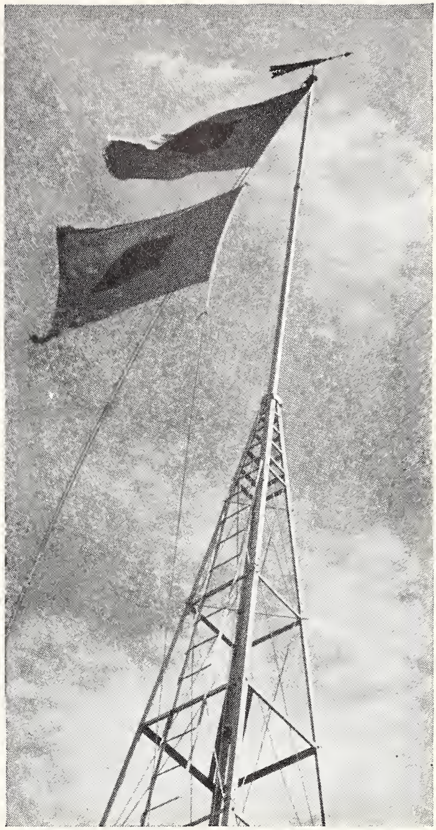
There is a type of cyclone that covers an even smaller area, sometimes less than a mile in width. In it winds may whirl as fast as 500 miles per hour or more. This is the terrible *tornado* or "twister" (Fig. 116). The path of a tornado is seldom much more than 300 miles long, and the

center travels along at 25 to 40 miles per hour. A tornado is tricky; it usually loops back on its path to hit a place more than once while skipping buildings no farther away than across the street. Sometimes it jumps over a few houses only to come down and hit again. A cyclone cellar is the only safe place to be when a tornado is near.

Weather Changes Along a Cold Front

Have you ever driven along a road into and out of a thunderstorm within a few minutes? A thunderstorm is called a local storm because it happens in a small area. It is often the mark of an advancing cold front. Every experienced camper or boat skipper knows that the tiny, high cumulus clouds which build up so quickly in a sky that has been cloudless may soon become the towering anvil-shaped clouds known as thunderheads. Compared to a warm front, a cold front rises steeply from the ground. It covers less territory and brings quick changes in the weather. These changes are: sudden thunderstorms (which usually occur in the summer), a sudden drop in the air temperature, and strong winds. This is followed by rapidly rising air pressure, clearing skies, and lower humidity.

When a cold front advances rapidly, air quickly rushes upward, thus producing violent updrafts (Fig. 113). These updrafts send warm, moist air up into much cooler levels of the atmosphere. There water vapor condenses. High thunderhead clouds begin to build up. The upper parts of these clouds are made up of ice crystals, and from the lower parts



STANDARD OIL CO. (N.J.)

115 "Hurricane coming!" is the warning signaled by these red flags with black centers. A cyclone with winds of 75 miles per hour is expected.

come great amounts of pouring rain. Sometimes raindrops are caught in the strong updrafts. As they are carried to higher, cooler air, they may freeze and take on a coating of snow or frost. When this happens, they become hailstones. As the hailstones take on weight, they start to fall. At lower levels they may gather more weight as more water vapor condenses on them and freezes. Hailstones may be blown upward and

BROWN BROTHERS

116 Take cover *fast* if you ever see a funnel-shaped cloud like this one, for a tornado is near. What may happen to a house in its path?

drop downward many times, each time gathering a fresh layer of ice, before becoming large enough to fall to the earth. Some hailstones are as big as baseballs. Needless to say, large hailstones may do a great deal of damage to crops, greenhouses, and other property.

USING WEATHER MAPS

You now have enough information about weather conditions and their causes to understand a weather map. The daily weather map sent out by the U.S. Weather Bureau has much more information than you need to use just now. This information is needed by local weathermen. An official weather map explains what each of the marks and numbers means. (See also Fig. 109.) The back of the map has more printed information about the symbols.

Send to the U.S. Weather Bureau for a series of daily maps. By placing one alongside another, you will be able to see how air masses and fronts travel across the country.

Lines on Weather Maps

Now look at the weather map in Fig. 114. The peculiar solid curving lines you see drawn across the map are called *isobars* (EYE-soh-bahrz). The letters *iso* mean "same"; the letters *bar* come from "barometer." Isobars join places that have reported the same barometric (air) pressure. The closer together the isobars are drawn, the more rapid are the changes in air pressure in the areas they cover.

You may also see broken curved lines on your map. These broken lines are *isotherms* (EYE-soh-thermz), joining the places that have reported similar temperatures.

Isobars and isotherms help anyone reading the map to see at a glance where the same conditions prevail. With this information, plus the readings of your own instruments, plus a glance at the clouds and another at the calendar, plus what you have learned about the causes of weather changes, you should now be ready to try your skill as an amateur weather prophet.

Your Work as an Amateur Weatherman

Start your work as a weatherman by sending for daily copies of the weather map. Then make a large chart with spaces for entering all the information you have gathered on one line straight across the chart. We suggest the headings shown in the sample chart.

You should do this kind of observing until you are able to predict future weather correctly for an average of three times out of four, or 75%.

First, you will have the pleasure of developing an important new skill, one which may be very useful to you. Second, you will be ready to help the U.S. Weather Bureau. Perhaps they will give you permission to hang a sign over your door reading:

METEOROLOGIST—CO-OPERATIVE OBSERVER FOR THE UNITED STATES WEATHER BUREAU

In war and in peace, our country depends upon the work of the amateur weathermen of America. Why don't you become one?

My Weather Chart

Date of observation	6/15	
Time of observation	12:04 PM	
Present air temperature	76° F.	
Present air pressure (barometric pressure)	100.2 millibars	
Percentage of relative humidity	54%	
Change in percentage of relative humidity	53% (8 A.M.) 60% (11 A.M.)	DO
Kind of precipation (if any)	None	NOT
Precipitation since last entry	None	WRITE
Direction of wind	East	IN
Speed of wind	1.7 mi. per hr.	THIS
Further remarks about the wind	gentle breeze	BOOK
Condition of the sky	Clear	
Type of front coming*	Warm	
Type of air mass coming*	cP, from Canada	
Approximate speed of coming front (or air mass)*	500 mi. per day	
My position with respect to the nearest high (or low)*	Due East	
U.S. Weather Bureau's prediction*	Fair	
My prediction	Fair	
What actually happened†	Fair	

* Get this information from the weather map. † Enter 24 hours later.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

maximum-minimum thermometer
barometer
stratus cloud
cumulus cloud
cirrus cloud
front
high
barograph
aneroid
altimeter
air mass
cyclone
low
hurricane
theodolite
psychrometer
anemometer
radiosonde
tornado
isobars
isotherms

1. winds blowing counterclockwise about an area of low air pressure
2. an instrument for measuring air pressure by means of a tube containing mercury
3. a heaped-up cloud
4. lines on a weather map connecting observatories reporting the same temperature
5. a thermometer that records the highest and lowest temperatures
6. an instrument used to find relative humidity
7. a layer of clouds covering a large portion of the sky
8. lines on a weather map connecting places reporting the same air pressure
9. an instrument that records air-pressure changes on a graph
10. the boundary between two air masses
11. a barometer that uses no mercury or other liquid
12. a high "mare's tail" cloud
13. a wind of 75 miles per hour or more
14. an instrument for measuring the speed of the wind
15. an area of low air pressure marked on a weather map
16. an aneroid barometer used for measuring the height above sea level
17. a large body of air having, level for level, the same temperature, pressure, and humidity
18. a violent windstorm noted for its funnel-shaped cloud
19. a radio and other instruments attached to a balloon which is sent aloft

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. Some facts the U.S. Weather Bureau gathers include the . . . and direction of the wind, the . . . and . . . of the air, the amount of . . . in the air, the kind of clouds and their . . . , and the number of inches of . . . . The Weather Bureau also wants to know the location of cold or warm, wet or dry . . . and the kind of . . . that is between them.

2. If you were making a mercury barometer, you would need a . . . tube than if you were making a thermometer.

3. At the top of a mountain 5,000 feet high, the mercury in a barometer tube will weigh . . . than at sea level.

4. It is more likely to rain when the relative humidity is . . . .

5. The amount of relative humidity is always written as the . . . of water vapor in the air compared to the amount the air could hold if the temperature remained the same.

6. Moisture collects as dew on objects when they have been . . . .

7. A Beaufort arrow showing a wind of 25 to 31 miles per hour from the northeast would be drawn thus . . . on a weather map.

8. Isobars on a weather map are . . . lines connecting places reporting the same . . . .

9. The oldest method of observing the approach of changing weather without the use of instruments is to observe the . . . and to note changes in their . . . and . . . .

10. A person who makes his own weather observations and reports them regularly to the U.S. Weather Bureau is called a . . . .

GOING FURTHER

In the Laboratory and Field

1. *Organizing a Weather Bureau in your school.* Divide into groups that will keep the records suggested on p. 239. Then study the facts, decide upon a prediction, and post it. Compare your predictions with the predictions of the U.S. Weather Bureau.

2. *Comparing centigrade and Fahrenheit thermometers.* Get a laboratory thermometer that is marked with both the Fahrenheit and centigrade scales. Compare the boiling point of water and the melting point of ice on the two scales. Then learn how to change from one scale to another by doing the simple examples given below.

To change centigrade to Fahrenheit, multiply by $\frac{9}{5}$ and add 32.

Problem: Change 20° C. to F.

$$20 \times \tfrac{9}{5} = 36$$
$$36 + 32 = 68$$

Answer: 20° C. = 68° F.

To change Fahrenheit to centigrade, subtract 32 and multiply by $\frac{5}{9}$.

Problem: Change 212° F. to C.

$$212 - 32 = 180$$
$$180 \times \tfrac{5}{9} = 100$$

Answer: 212° F. = 100° C.

Now change:

25° C. to F.
50° F. to C.
140° F. to C.
50° C. to F.

3. *Making a weather movie booklet.* Draw a United States map, about $2\frac{1}{2}$ inches by $1\frac{1}{2}$ inches, showing just the outline of our country. Draw it on a piece of cardboard. Cut out the pattern and trace it on 25 or 30 small pieces of paper. Draw in the position of the highs and lows as they appear on the daily weather map for about two weeks. Use maps at a time when the highs and lows are moving quite rapidly. Then bind the book at the narrow edge and flip it open with your finger. You will have a moving picture of weather changes.

4. *Collecting clouds.* If your camera is a kind to which you can attach a filter, buy a yellow (K–2) and a red filter. Take them along with you on a cloud hunt. Try each filter separately. Which one works better? Take pictures of clouds of various types, to enlarge and exhibit.

Put on Your Thinking Cap

1. Here are certain weather conditions observed in your town. The barometer is falling, the temperature is rising, the wind direction is changing from west to east and its speed is increasing, and low stratus clouds are forming. Explain your weather prediction.

2. Name five good ways to get correct weather information.

3. Why are the following statements about the weather untrue?

a. A high barometer always means fair weather.

b. Hail is harmless.

c. Dew falls on cloudy nights.

Adding to Your Library

1. Request from the U.S. Weather Bureau, c/o the Department of Commerce, Washington, D.C., the class packet for the study of weather. Ask them to include, if possible, the booklets *Cloud Forms*, *Instructions for Co-operative Observers*, and *Weather Forecasting*. Read these from cover to cover if you want to be a weatherman.

2. *The Boy Scout Handbook on the Weather* is excellent for those who want to become amateur weathermen.

3. *Cloud Study* by F. H. Ludlam and R. S. Scorer, Macmillan, 1958. A little book of eighty pages full of pictures and photographs.

4. *The Wind and the Weather* by Joe Bolton, Crowell, 1957. Joe Bolton, a favorite TV weather reporter, gives you a happy combination of entertainment and information.

5. *Hurricane* by Marjory Stoneman Douglas, Rinehart, 1958.

6. *Hurricanes and Twisters* by Robert Irving, Knopf, 1955.

7. *All About the Weather* by Ivan Ray Tannehill, Random, 1953, covers all the common and some uncommon facts about the weather.

8. *Weather Almanac* by J. Henry Weber, News Syndicate, 220 East 42nd St., New York, N.Y., 1954. Gives complete data on weather and astronomy for the New York City area, plus climate data for the entire United States.

117 This sixteen-year old high school student built these weather instruments herself, and you can build ones like them if you try. *Project:* Get together with your classmates and plan an exhibit of those you build.

SCIENCE SERVICE

A Bit of Research

Make an appointment to visit your local office of the U.S. Weather Bureau and make pictures of the weather instruments that are used by the experts. Prepare a set of questions in advance, which you can hand to the man who will be your guide. During the tour, note his answers carefully.

Careers for You

People who make a lifework of weather science are called *meteorologists* (mee-tee-er-OL-uh-jistz). Ask your guidance counselor, or write to the college of your choice and find out what kind of courses you should study in high school if you want to become a meteorologist.

CHAPTER 12

Weather by the Season

Spring, summer, autumn, winter. Why don't we have summer only? Why must we have seasons? One part of the answer is 93 million miles away. Another part is in the way the earth slants.

IF YOU HAPPENED to live in Labrador or Scandinavia, you would have only two seasons — summer and winter. The ancient Anglo-Saxons of England and the early North American Indians divided the year simply into cold and warm seasons. In the tropics, wet and dry seasons are the only ones that matter. Some places, such as Burma and India, have three seasons — cold, hot, and rainy. There the rainy seasons and the winds that come with them are called *monsoons*. The Melanesians (mel-ah-NEE-shanz) of the southwest Pacific have even more seasons. We in the temperate zones have four seasons — spring, summer, autumn, and winter.

WHAT CAUSES SEASONS?

From your daily experience, you know that the length of day and night changes with the seasons. During summer the day is longer than the night. And in winter the opposite is true. What is the explanation?

From your work in Unit 3 you know that the earth rotates on its axis once every 24 hours. Also, one-

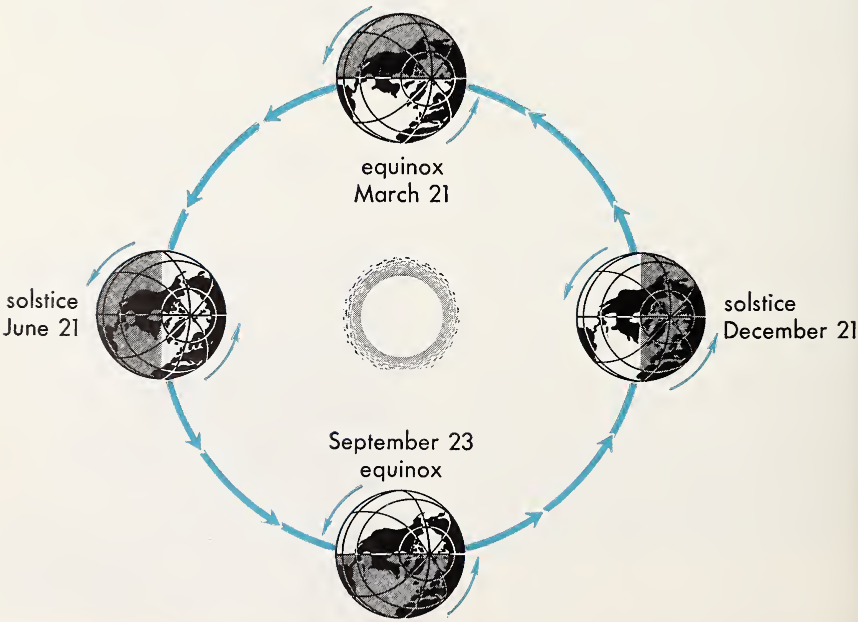
half of the earth is always in the dark, and the other half is always in the light. Thus you would expect all parts of the earth to have 12 hours of daytime and 12 hours of nighttime every day in the year. But this is not so.

The reason this is not so is explained by Fig. 118. Examine it carefully. Notice that the axis upon which the earth rotates is not at right angles to a line drawn from the sun to the earth's axis. Do you see it is tilted at an angle of 23.5 degrees? The direction of this tilt is such that the North Pole of the earth points toward the North Star. Figure 118 also helps you to see what this tilting of the earth's axis at 23.5 degrees has to do with the length of day and night.

As you examine Fig. 118, you will note that, during the summer in the Northern Hemisphere, the north polar region is tilted toward the sun. Do you see that in this position the sun's rays cover the entire Northern Hemisphere? If you could see the South Pole, you would find that it is in complete darkness during the northern summer. Therefore, if you live in the North Temperate Zone, your region spends more than half of each 24 hours in the sun's rays in summer. In summer, the day is, therefore, longer than the night. In winter, the night is longer than the day.

When the North Pole is tilted away from the sun, the South Pole is tilted toward the sun. Thus, while the Northern Hemisphere is having short days and winter, the Southern Hemisphere is having long days and sum-

118 This diagram shows the positions of the earth in its orbit on the days that mark the beginning of each of the four seasons. Half the earth is always in darkness. Its axis always points toward the pole star.



mer. At that time the Southern Hemisphere spends more than half of every twenty-four hours in the sun's rays. Can you see also from your study of Fig. 118 that in December the North Pole is in complete darkness during the entire 24-hour period? At this time the North Pole is turned away from the sun and gets none of its rays. Therefore it is true that the length of the days and nights changes with the seasons. In the North Temperate Zone, there are long days in summer and short days in winter. If there were no other way to note the march of the seasons, we could do it simply by noting the changes in the length of the days and nights.

The March of the Seasons

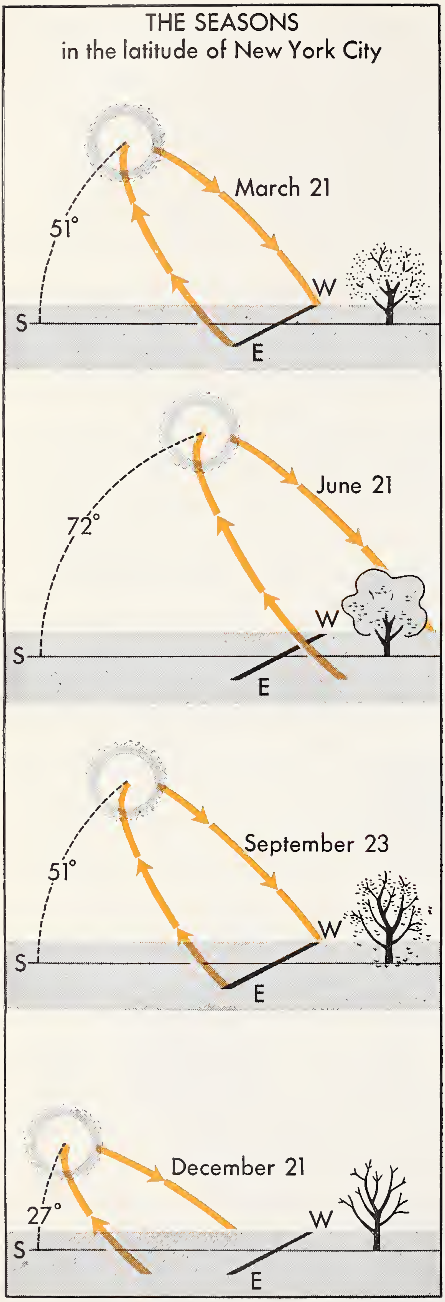
Of course we have the calendar to help us keep track of the seasons. March 21 is generally the beginning of spring. June 21 marks the beginning of summer, September 23 introduces us to fall, and December 21 is the first day of winter. (These dates may vary by a few days.) Have you ever asked yourself why the seasons start on or about these dates?

To answer this question, examine the position of the earth in its relation to the sun on these dates. Study Fig. 118 carefully as you read this. About March 21 the length of the night in the Northern Hemisphere is the same as the length of the night in the Southern Hemisphere. On March 21, at the equator, the sun is exactly overhead at noon. The earth is in the position shown in Fig. 118. As you can see, in this position the axis of the earth is not tilted away from or toward the sun. Therefore both hemispheres get equal amounts of light on March 21. On September 23, the earth is in a similar position but on the opposite side of its orbit. Again the days and nights in both hemispheres will be the same in length. These two days (March 21 and September 23) are called the *equinoxes* (EEK-wih-noks-ez). *Equinox* in Latin means "equal night."

The Solstices

From March 21 to June 21, the earth continues its revolution around the sun. Slowly the North Pole end of the axis tilts *toward the sun.* On June 21, the sun at noon appears to be directly overhead at a latitude 23.5 degrees north of the equator. This latitude is called the Tropic of Cancer. For a few days the sun appears to remain at about this latitude. For that reason June 21 is called the *summer solstice* (SOL-stiss). *Solstice* in Latin means "sun standing still."

Now if you study Fig. 118 again, you will see that in the winter season on December 21, the earth is directly opposite its June 21 position on its orbit around the sun. The North Pole now is tilted 23.5 degrees *away from the sun.* Now the sun's rays shine longer each day on the Southern Hemisphere. The sun is directly overhead at noon over latitude 23.5 degrees south of the equator. This latitude is the Tropic of Capricorn. For a few days, the sun appears to remain at this latitude before it starts northward again. This time, about December 21, is called the *winter solstice*, the beginning of winter in the Northern Hemisphere. The same date marks the summer solstice in the Southern Hemisphere. Figure 119 shows the apparent path of the sun and its noon position over a period of a year in the latitude of New York City. We



say *apparent* path because it is, of course, the earth that moves around the sun. The sun only *appears* to move and change its position.

Although the sun is highest in the sky at noon, it is never directly overhead north of the Tropic of Cancer or south of the Tropic of Capricorn. The Torrid Zone between these two tropics is 47 degrees wide.

The basic reasons, then, why we have our seasons are:

1. The earth revolvcs around the sun (once during the year).

2. The earth's axis is tilted 23.5 degrces.

THE FOUR SEASONS

Living things need no notice from the Weather Bureau to tell them when a new season has come. Each season has its own effects upon all living things.

Spring

For those who need a date, March 21 is the official first day of spring, but the actual date may be one or two days later or earlier. This is true also of the dates marking the beginning and end of the other seasons.

As you remember, on or about March 21, the sun seems to cross the equator and is right overhead at noon for all who dwell on that line. On

119 The latitude of New York City is about 41 degrees. Along this line of latitude across the United States, the sun rises directly in the east twice a year. Its height in the sky at noon is different for each day. It is lowest the day winter begins, and highest the day summer starts. *Project:* Try to make a similar "map" for the place where you live.

March 21, the spring equinox, the night is the same length in the Northern Hemisphere as in the Southern Hemisphere. The sun rises directly in the east and sets directly in the west. As you can see in the table, all parts of the world have 12 hours of daylight and 12 hours of darkness on the day of the spring equinox, March 21.

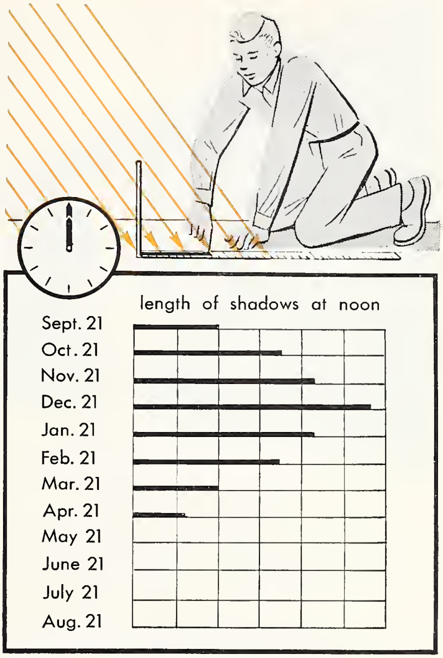
Notice how the hours of daylight gradually increase in all parts of the Northern Hemisphere from December 21 until June 21. Right there you have part of the explanation for the change from winter weather conditions to summer weather conditions. From December 21 to June 21, the hours of sunlight increase in the Northern Hemisphere. This happens because the North Pole and the Northern Hemisphere are tilted more and more toward the sun during these months.

Hours of Daylight

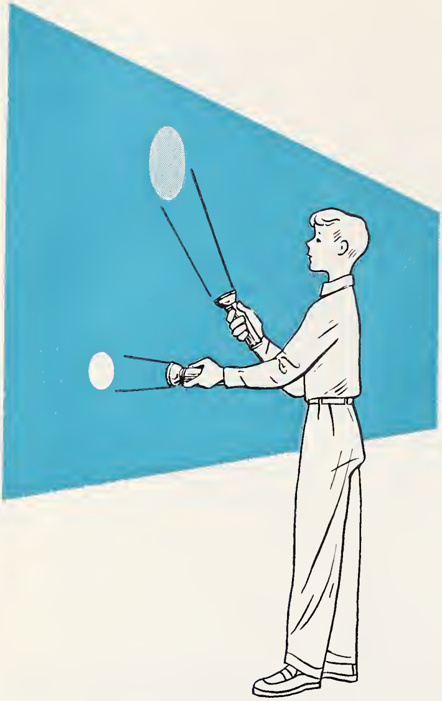
	Dec. 21	Mar. 21	June 21	Sept. 23
NORTHERN HEMISPHERE				
North Pole	0	12	24	12
Arctic Circle	1	12	23	12
40 degrees north latitude	9	12	15	12
Tropic of Cancer	10½	12	13½	12
EQUATOR	**12**	**12**	**12**	**12**
SOUTHERN HEMISPHERE				
Tropic of Capricorn	13½	12	10½	12
40 degrees south latitude	15	12	9	12
Antarctic Circle	23	12	1	12
South Pole	24	12	0	12

Slanting Rays and Changing Seasons

The other half of the reason for changing seasons lies in the changing slant (angle) of the sun's rays as they strike the earth. The sun's rays themselves do not slant. It is the earth that changes its position in such a way that the sun's rays appear to slant in at changing angles. Figure 119 shows how much more the sun's rays seem to slant on December 21 than on June 21. You can prove this by measuring the length of a shadow at noon on each of those dates. The boy in Fig. 120 shows you how to do this. The more the sun's rays slant, the longer the shadows it casts. For the same reason a late-afternoon or early-morning shadow is longer than a noon shadow.



120 *Project.* Measure the sun shadows and make a chart of your observations. Why should all measurements be made at the same time of day? Why is noon a good time to make these measurements?



121 Try this: Point only one flashlight first at a slant and then straight toward the wall. Which spot of light is brighter? Which spot of light is larger? Why?

The sun's light is spread over a wider surface as the slant of its rays increases. Figure 121 demonstrates this.

We suggest that you use a flashlight for the light of the sun. That way you will not have to wait three to six months to complete your observations. Try holding your own flashlight in the same positions against the wall of your room. While you do this, have a friend measure the size of the spot of light with a ruler.

What do your results show? You will find that the size of the spot of light is smallest when the flashlight is pointed straight at the wall. The size of the spot of light grows bigger as the flashlight is turned toward the ceiling so that the rays slant.

Let us suppose that in the summer the sun's rays cover just 100 acres or 100 square blocks of land in a certain part of the Northern Hemisphere. In the winter, as the earth's axis tilts away from the sun, the sun's rays which covered 100 acres now spread over more than 100 acres of land. This is so because the sun's rays in winter come in at a greater slant and thus cover more land. This is what your flashlight experiment has just shown you. Since the same number of rays bring the same amount of heat, it follows that less heat will be supplied to *each* acre in winter than in summer. Therefore the weather will be colder in winter than in summer.

You may have thought, as some people do, that it is colder in winter because the earth may be farther from the sun. Actually the opposite is true. The earth is about 3 million miles closer to the sun in January than it is in July. It is the angle at which the sun's rays hit the earth and not the earth's distance from the sun which causes our changes of temperature from season to season.

As the sun travels higher and higher in the sky (Fig. 119) from December 21 to June 21, the time the sun is in the sky grows longer and the number of hours of daylight increases. The land, the water, and the air in the Northern Hemisphere are exposed longer to the sun's rays and so take more heat from them. Therefore the weather becomes warmer and living things behave accordingly.

We have left one fact out of this

picture until now. Do you know what it is? It is the effect that passing through the earth's atmosphere has upon the sun's rays. The rays have a longer trip through the earth's atmosphere when they come in on a slant than they do when they come in at a steeper angle or a right angle. Scientists have found that the atmosphere acts as a kind of filter or screen for certain rays in sunlight. These are the rays that have the greatest effect on the growth of plants and that give us a coat of tan. They are the ultraviolet rays. From March 21 to September 23, when the sun's rays are less slanting, more ultraviolet rays reach the earth. This is another reason why spring and summer are not only warm seasons but the best seasons for plant growth (and for getting suntanned).

To most of us, the air feels balmy and springlike when the temperature rises to between 50° F. and 60° F. A study of the average daily temperatures in this country for a period of 46 years showed that average temperatures of 50° F. begin as early as February 1 in some of our southern states but are not common in northern New England until May 15. On what date does your area begin to have an average daily temperature of 50° F.?

Summer Weather

Farmers and astronomers do not always agree on the date of the first summer day. The official first day of summer (according to astronomers) in the Northern Hemisphere is June 21. Then the sun seems to be directly above the Tropic of Cancer, 23.5 degrees of latitude north of the equator. As it is seen from the earth, the sun appears to stand still at its summer solstice for a few days. Then it appears to start moving south toward the equator (see Fig. 119).

When temperatures average about 68° F., summer has come. Some parts of the United States never have average summer temperatures over 68° F. Summer temperatures arrive as early as March 1 in southern Florida and as late as July 1 to July 15 in the mountainous sections of the North and West. To some places in the far north of the United States or on mountaintops, summer never comes in this sense. The *World Almanac* has average monthly temperature facts for dozens of cities in the United States and its possessions. Check up on the facts for the part of the country in which you live.

Thunderstorms and Lightning

Thunderstorms, of course, bring *lightning* and *thunder*. Which comes first, the thunder or the lightning? Lightning comes first, although many people believe that the opposite is true.

There are many theories to explain how lightning is made. All we need to understand now is that clouds can become charged with electricity. The electrical charges, you may remember from your earlier science work, are of two kinds, positive (+) and negative (−). It is thought that under special conditions a cloud may develop positive charges in one part and negative charges in another part. Or one cloud may develop negative charges, another only positive charges. Positive and negative charges attract each other. When the number of negative charges has become large enough, they jump to a cloud having

positive charges. We then say that the cloud with negative charges is discharged. This discharge in the form of a flash is lightning. A discharge of lightning may also take place between a cloud and the earth or some object on the earth, such as a tree, a person, a building, or a lightning rod.

The discharge of lightning heats and expands the air in its path. The gases in the air are pushed aside and pressed into a small space. As the air expands suddenly and then bounces back, you hear a loud noise. This noise is thunder. The rolls and rumbles of thunder you hear are nothing more than echoes bouncing off masses of clouds.

Standing under a tree during a thunderstorm is a good way to ask for injury or death. At the first hint of an approaching storm, what should you do if you are swimming or playing golf or working in an open field? You should seek shelter in a house. If you are in an automobile during a thunderstorm, you need not leave it, for all-metal automobiles are safe shelters to be in. During a severe lightning storm, beware of parking a car under a tree that may topple over and crush it.

Autumn

Autumn begins when the sun is again over the equator at noon, on or about September 23. On this day, you will find that conditions are similar to those at the spring equinox. As on March 21, the day and the night are equal in length. The sun rises directly in the east and sets directly in the west. But we know it is not exactly the same as spring, for now the days are growing shorter instead of longer. At the end of September, Daylight Saving Time for those states that have it usually comes to an end. Warm clothes are taken out of moth balls. Hay fever remedies are put away. Fireplaces are lighted and thoughts turn to Thanksgiving.

The weatherman has another way of marking the turn of the seasons. He does not go by the calendar but by the thermometer. Autumn for him has two parts in the months of September, October, and November — Indian summer and the cool fall. When average air temperatures are between 67° and 50° F., we have Indian summer. The cool fall days are those when the temperature may go as high as 50° F. or as low as freezing (32° F.). The temperatures for autumn days average about the same as those for spring days. Along seacoasts the ocean and other large bodies of water cool off slowly. This has the effect of keeping the weather warm through late autumn because the water keeps some of the summer heat. The slow warming up of the oceans in spring keeps the cold weather of winter on into the early summer near the coast.

One more thing helps to explain some of the mild days of autumn. The warm air masses of the tropics seem to be able to come farther north more often than they do in the spring. Whenever one of these air masses manages to go north it makes the weather milder than the seasonal average.

Dew, Fog, and Hurricanes in Autumn

By what other conditions is autumn known? This can be answered in three words: dew, fog, hurricanes.

ACME

122 What happened? Before you turn the page around to look at the answer, see if you can figure it out. Here are some hints. It happened in September. The Weather Bureau warned it would happen. Damage covered many miles. A HURRICANE DID THIS DAMAGE.

Hurricanes have already been described on p. 236. Figure 122 illustrates the kind of damage a hurricane can do. September and October are the principal hurricane months along our southeastern and eastern coasts.

Dew and fog have also been mentioned before (p. 216). Now we are ready to study them further. What kind of weather aids the forming of dew and fog? If you see a heavy dew, you may be sure the night has been clear and calm. If the night is windy, very little dew forms, for wind makes water evaporate quickly. Therefore, a heavy morning dew means that the night was calm, not windy. Frost, also, forms only on calm nights. When the temperature of the air near the earth is below freezing, frost rather than dew is formed.

Fog usually forms in the early morning. It can form at any time, however, but forms most easily when humid (damp) air is cooled. Like dew, fog forms best when the air is not windy. The gentle mixing of cold air with warm, humid air will cause a fog. A fog is really a cloud close to the earth. Fogs formed at night usually disappear when the sun comes up and when its heat is enough to evaporate the tiny droplets of moisture which form the fog.

Smoke in the air, on the other hand, may cause fog because the droplets of water have more dust particles upon which to form. A mixture of fog and smoke, often called *smog*, is much worse to deal with because the tiny smoke particles are in the air in very great numbers. Smog, therefore, is not so easy to get rid of as fog. Airplane landing fields have been cleared of fog by the heat from large amounts of burning gasoline — a costly way to do it. It is hoped that in the future sprinkling

dry ice or spraying fine streams of water from airplanes will clear away the clouds around airports at much less cost. Maybe one of you will find a way to solve this problem.

Winter

For many people winter is the best of all seasons, and for some it is the worst. Astronomers say winter begins on December 21 in the Northern Hemisphere. On that day, as you remember, the sun is above the Tropic of Capricorn at noon (Fig. 118). The sun is low in our sky at noon in the United States, rising late and setting early. The first day of winter is the shortest day in the year. In ancient times, people had great feasts to show their happiness that the days were growing longer again. These ancient feasts later became holidays for entirely different reasons.

Even though the days are growing longer in January and February, it is then that we have the coldest weather of the winter season. During winter the northern states and Canada are covered with a blanket of snow.

A winter day is one during which the average temperature is 32° F. or less. Some parts of the United States have this average daily temperature as early as November 20, others as late as December 15, and still others seldom have temperatures as low as this. Winter is a season when most woody plants have lost their leaves and animals look for warmth.

LIVING THINGS AND SEASONAL WEATHER

Not all animals can stand the seasonal changes in the weather the way humans do. Some warm-blooded animals are able to stand cold weather and remain active all winter. Others find it is best for them to travel south or remain quite still in a protected place. Fish and frogs, you remember, are cold-blooded. This means that their body temperature goes down as the temperature of their surroundings goes down. But there is a limit. For them it is fortunate that the ice in a pond floats, leaving a certain amount of warmer water and mud unfrozen at the bottom. Here these cold-blooded animals stay throughout the winter, living quietly on food stored in their bodies.

Adapting to Cold Weather

Plants also have temperature limits beyond which they cannot live. Some plants, like orange trees, orchids, and palms, do not grow in the northern parts of our country. They need warm, moist weather. The plants that do live through the winter in the north become *dormant* (seem to sleep) during cold weather. During the dormant stage, many trees have lost their leaves but are very much alive. Other trees, such as the evergreens, keep their leaves. Like the dormant animals, such as bears and groundhogs, they live on stored food.

Many creatures, like certain birds and the monarch butterfly, go south when the winter weather "kills" the animals or plants they feed on. This seasonal traveling is called *migration* (my-GRAY-shun). It is surprising how far some birds travel when they migrate. How they find their way back to the same place year after year is a mystery to be solved by the scientists of our country and of those nations to which the birds migrate. Scientists of different countries

have been working together for a long time on this problem.

The mystery of these yearly mass flights is no harder to understand than the sleeping done by many thousands of animals during the cold months. This winter sleep is called *hibernation* (hy-ber-NAY-shun).

A female black bear hibernates in such a deep sleep that she can give birth to cubs without seeming to be aware of having done so until spring. Many insects and similar animals pass the winter hidden in rotten wood, in soil, or in the bark of trees.

It all adds up to this: If you want to live in any region, you either have to like the weather, make the most of it, forget it, or suffer through it. Some living things, such as lizards and snakes, crawl under rocks to hide when the sun is too hot. Others, like the woodchuck, crawl underground and "sleep the clock around" when the weather is too cold. Some birds, such as the golden plover, fly thousands of miles southward across continents and oceans when weather conditions change. Others — people we know — spend their summers on New England beaches and then *migrate* to Florida or California to spend their winters — again largely on the beaches. Others stay put but change their indoor weather by means of heating and cooling systems built into their houses.

Keeping Comfortable at Home

Where weather conditions are not to their liking, people may make an air-conditioned indoors in which to live.

Before you can make a house a home, you have to make the house a shelter from the changing weather. It is in this sense that we shall consider the problem of better housing in the next chapter. Since we cannot make the outdoor weather to our liking, let us find out how we can build our houses for better health, safety, and pleasant indoor weather, regardless of the season.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

monsoon	lightning	hibernation
summer solstice	thunder	migration
winter solstice	smog	

1. the act of remaining quiet or asleep during some or all of the winter season
2. an electrical discharge which usually takes place during a thunderstorm

3. a seasonal wind of India

4. a mixture of fog and smoke

5. seasonal traveling from one place to another

6. for the Northern Hemisphere, the time when the sun seems to be at its farthest south point at noon

7. for the Northern Hemisphere, the time when the sun seems to be at its farthest north point at noon

8. the sound caused by the rapid expansion and bouncing back of heated air when lightning passes through it

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. Some animals, such as the . . . , migrate when the seasons change.
2. Other animals, such as the black bear, . . . when winter comes.
3. Astronomers say the seasons change on . . . , . . . , . . . , and . . . .
4. These dates are based upon the position of the . . . in the sky.
5. Because land warms up and cools off more rapidly than water, places near large bodies of water have . . . winters and . . . summers than places near the center of a large continent.
6. All seasonal changes are the result of the . . . of the earth around the sun and the . . . of the earth's axis.
7. The hours of daylight in the Northern Hemisphere are longest on or about . . . .
8. The hours of darkness are longest in the Northern Hemisphere on or about . . . .
9. There are about 12 hours of daylight and 12 hours of darkness all year at the . . . .
10. The nights are of equal length in the Northern and Southern Hemispheres on . . . and . . . .

GOING FURTHER

In the Laboratory and Field

1. *Research on temperature of the air.* What has been said about the changes of air temperature for the country as a whole may not be true where you live. The best way to find out is to do some research. With the help of your classmates, take the average of the highest and lowest temperatures where you live every day for a year. Using the temperatures mentioned in this chapter, find out when the growing season begins and ends in your part of the country. Compare these dates with the dates the astronomers say the seasons begin and end in the North Temperate Zone.

2. *Water and air temperatures.* If you live near a large body of water, make a daily record of the temperature of the water and compare this with the temperature of the air. You can mark these facts on a piece of graph paper, using different colors for the two lines showing the temperatures.

3. *Plants and temperatures.* Would you like to have a garden? Open a copy of

America's Garden Book by Louise and James Bush-Brown, Scribner, 1952, p. 1171, and you will find a list of things to do for and to your garden during each season of the year. The flower garden, the vegetable garden, the lawn, trees, shrubs, and fruit must be given special care at each season. For further information, write to the U.S. Department of Agriculture in Washington, D.C.

Put on Your Thinking Cap

1. Why does the Northern Hemisphere have its warmest weather during July and August, when the earth is farthest from the sun?
2. What would be the probable effect upon the earth and upon living things if the slant of the earth's axis should slowly increase to 50 degrees or decrease to about 5 degrees?

Adding to Your Library

1. Write to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., for a copy of *Normal Weather for the United States* by J. B. Kincer. This booklet tells what kind of weather may be expected in various parts of our country, month by month, during the entire year. It is a reference book any committee reporting on this topic will need.
2. Write to the National Audubon Society, 1130 Fifth Ave., New York, N.Y., for a list of their pamphlets on how plants and animals live through the winter. You may want to use the facts they will give you to build the right kind of houses and feeding stations for birds in your neighborhood.
3. If you might be interested in weather science as a career, send for this pamphlet:

   Meteorologists, Occupational Briefs No. 256, Science Research Associates, Chicago, 1958.
4. If you would like to subscribe to the U.S. daily weather map, you may do so by writing to the Superintendent of Documents (see address above).

A Bit of Research

In various parts of the country there are many old sayings about the weather. Some are true, and some are not true at all. Why not collect a few of these sayings and test them? Here is one to begin with:

> When dew is on the grass
> Rain will never come to pass.

Protecting Yourself Against The Weather

Man, using science, has tried to make weather perfect for himself. In his home, of course! But once he goes outside, the weather gets at him. There he tries to live with the weather. Knowing how is important.

Suppose you are going ice skating and want good protection from the wind. Why will you choose a leather windbreaker? Look at the picture above. Why is the man wearing the clothing he is? Look at a piece of leather and at a piece of woven or knitted material with a hand lens. You will then see why leather is better able to keep wind from your body. Leather has tiny pores, but compared to them the most tightly woven material has great holes. In a strong wind the air goes through these holes, but leather keeps the wind outside.

On a cold day a leather jacket will keep out the wind, but you would freeze if you wore nothing between the leather and your skin. Unlined leather gloves do not keep your hands warm. It is the lining of the gloves, such as fur or wool (as in the parka shown in the picture above), and the several layers of clothes under your leather windbreaker that keep you warm. Why?

Notice again the air spaces between

the wool fibers or between the hairs of a fur lining of a glove. These are dead air spaces in which the air cannot circulate. When air cannot circulate, it gives you good protection against the loss of heat from your body. Fur and wool clothing, therefore, help to keep you warm by keeping the heat of your body inside the clothing. Linings in clothing do the same thing.

The Right Clothes

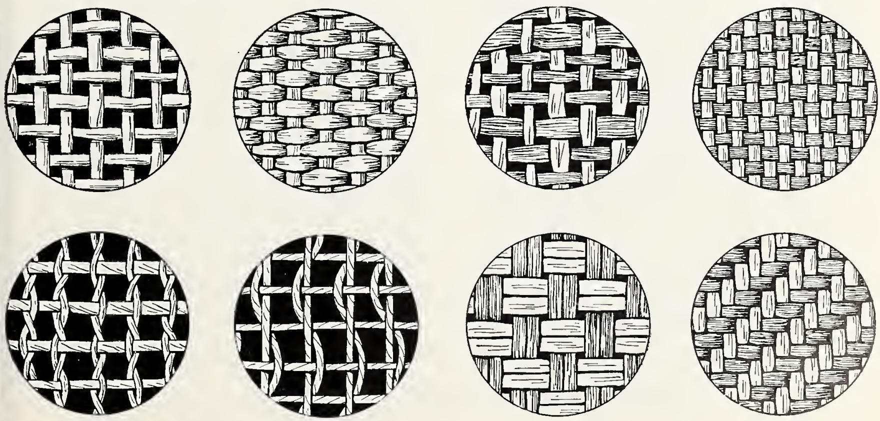
If the choice of material is the first matter of importance, the second is the weave of the cloth (Fig. 123).

To understand what we mean by the weave of the cloth, take out your handkerchief. Hold it up to the light. Can you see the light through it? Repeat this test with single layers of the materials in the clothing you wear. Do you notice any difference in the size of the spaces between the threads or fibers? Is the knitted sweater you sometimes wear woven as tightly as the blanket on your bed? How does it compare with the weave of your coat? Compare the weaves of the garments you wear in summer with those you wear in winter. Do you suppose the closeness of the weave has anything to do with keeping you warm (Fig. 123)?

Now look at the color of the material you are wearing. Do colors have anything to do with keeping you warm or cool?

Make this test yourself. Take two pieces of the same kind of material, one white, the other black. Place both pieces of cloth in the direct rays of the sun. Under each place a thermometer. Check the temperature of each at the start of the experiment and at the end of 1 minute, 2 minutes, 3 minutes, 4 minutes, and 5 minutes. You will find that the thermometer under the black cloth will show a greater increase in temperature. Dark colors take in more heat from the sun's

123 Common weaves look like this when seen under a microscope. The top four are all plain weaves, but they differ in quality because each has a different thread count per square inch. The two open weaves (*lower left*) are used for curtains. The next weave is used for one type of cotton shirt. The one at the lower right is used in cloth for suits.



rays than lighter colors. What colors are more popular in summer than in winter? Why?

The fit and finish of clothes also have a great deal to do with your comfort in wearing them under different weather conditions. Have you ever noticed that some well-made overcoats for winter wear have an elastic in the sleeve lining to keep the cold air out of the sleeve? For summer or warm weather our clothes are of a loose fit to allow air to circulate as much as possible. There is a scientific reason for this.

In summer your comfort depends upon keeping your body cool. The air circulating freely through loose-fitting garments allows your perspiration to evaporate faster. You may think it strange for a baseball pitcher to wear a sweater or long-sleeved shirt in summer when he is working so hard. Too much cooling from evaporation might tighten his arm muscles and thus ruin his pitching skill for the day.

When you choose clothing, keep in mind the weather conditions under which you will wear it. Think about the fiber in it, its weave, finish, color, weight, and fit.

If you pay attention to what other people are wearing, you will often see that their clothes follow fashion rather than a choice based on common sense. Are the following choices based on fashion or the need for protection from the weather?

1. The wearing of furs in summer.
2. The wearing of open-toed shoes in rainy weather.
3. The wearing of overshoes (rubbers) in rainy weather.
4. The wearing of a scarf on a cold day.
5. The wearing of tight-fitting gloves on a cold day.

Of course you can give many other examples, but let us go over those in the list you have just read. Furs in summer are surely not needed for warmth, and open-toed shoes give the foot no protection on a rainy day. Overshoes give protection against rain or snow because the rubber keeps water out. They should be taken off indoors because the rubber does not allow body moisture to get out. Leather shoes allow for some evaporation, which is good for your feet. A scarf is good protection, but if it is of rough material, it may cause a rash where it rubs against the skin. Finally, do not wear a tight-fitting glove on a cold day if you want warm hands. The glove slows the circulation of blood in your fingers. If you do not have proper circulation of the blood through your fingers, your hands will not keep warm.

As you go about, notice some examples of the poor use of clothing. Are you sensible about the way you use yours?

HOUSING

To choose a good home for weather protection you may begin by deciding what you want your dwelling to do for you. This will depend upon your age, health, occupation, and the part of the country in which you are going to live. In the deep South a good cooling system may be more important than a good heating system. In Vermont or Maine and other sections in the North the opposite is true. In other parts of the country, both heating and cooling systems are wanted.

Indoor Weather Made to Order

In an area having cold weather, a house must have a heating system. The Indians used to build open fires in their tents and houses. In addition to the danger of setting fire to the house or tent, this method often filled the dwelling with smoke. Fireplaces were an improvement but still dangerous. If a room in which open flames are used for heating has poor ventilation, the people may fall asleep and die because the flames use up too much of the oxygen and replace it with poisonous gases. Furthermore, most of the heat from an open fireplace goes up the chimney. Only the side of a person's body facing the fire is warmed by its heat.

Man has tried for a long time to find better ways of getting more heat from less fuel. What do we need to know about heat?

How Heat Travels

Homes and public buildings became more comfortable places as man learned more and more about how heat travels. It was natural for men of old to heat their caves and later their tents and houses by *radiation*. The sun heats the earth by sending out its heat rays, and rays of heat from a fire tell us it is hot. We do not burn our fingers by putting them in a flame because the flame sends out radiations that warn us of its heat.

Heating a room by radiation is still common practice. After all, what do we call those things that heat some of our rooms? We call them radiators, don't we? Just what is a radiator? The word itself is misleading. While it is true that a radiator radiates heat, it does much more. Have you ever noticed the air wiggle over a hot radiator? As the air touching a radiator is heated, it rises. Cooler air takes its place and is heated and in turn is pushed upward by more cool air until the room is filled with air that has been warmed. The wiggles you see above the radiator are currents of rising air. A current of this kind is part of a *convection current*, that is, a current that carries heat. Actually, in some types of hot-water heating systems the radiator is called a convector.

This method of carrying heat has an advantage over an open fireplace, for you no longer have to stand or sit near the source of the heat. The air that warms you surrounds you, making you as warm on one side as on the other. Thus heat travels by convection as well as by radiation.

Some of the most modern homes have no radiators, and yet they are heated by radiation. The whole floor or the walls are the radiators, for they have hot-water or steam pipes hidden inside them. Heating a room in this way is called *radiant heating*.

Heat travels a third way — by *conduction*. If you heat one end of a nail, the other end will soon become too hot to hold. The heat causes the molecules of iron in the nail to move faster. This increase in motion is passed or conducted from molecule to molecule until the whole nail is hot. The pipes of a radiator become hot in the same way, getting their heat directly by conduction from the hot water or steam flowing in them.

This knowledge about how heat travels has made it possible for us to create indoor weather made to order for our comfort. Let us see how a house can be built to make use of our knowledge of radiation, convection currents, and conduction.

COMPARING CENTRAL HEATING SYSTEMS

Long ago homes had just one room and a wall of one thickness of material. Today most of the houses we live in have a number of rooms, often on more than one floor, and the walls have several thicknesses or a space between an inner and an outer layer. In a *central heating system* the heat is sent from one furnace (usually in the basement) to all the rooms in the house. There are several kinds of central heating systems. Each has its special advantages and disadvantages. The three main kinds of central heating systems are: hot (or warm) air, hot water, and steam.

Each system, however, uses a furnace, which supplies the source of the heat. Regardless of the system he uses, the homeowner must decide whether he will use a furnace that burns gas, oil, coal, or wood. The kind that is best depends upon the care and cost. Many people cannot or will not bother with fuels that leave ashes. Other people prefer to buy the cheapest fuel and to go on using an old furnace in spite of the extra care it needs. The cost of fuel depends largely upon where you live. For instance, coal, gas, and oil are easy to get in most parts of the country, but wood is in better supply in certain places. Can you figure out why homeowners with limited amounts of time and strength often prefer gas and oil as fuels?

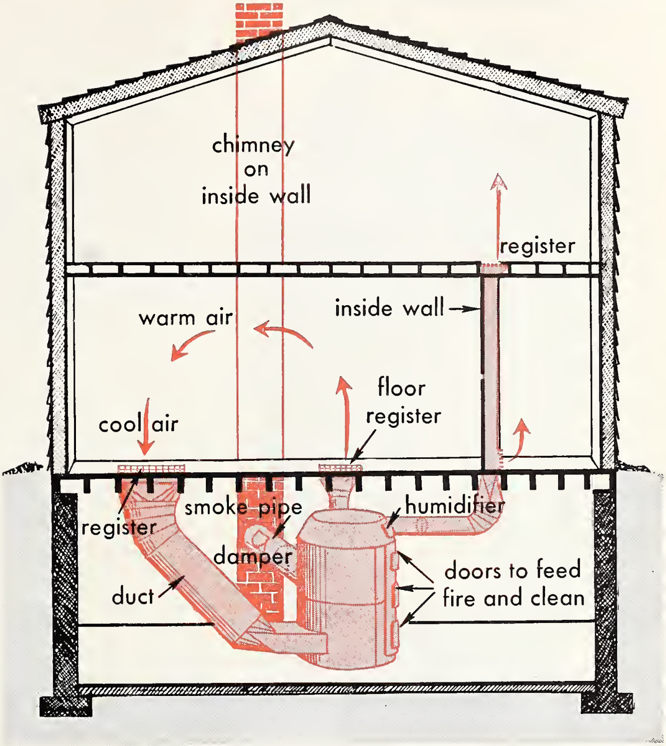
Hot-Air Systems

In the early types of hot-air systems, fresh air entered from the outside and was heated. To save fuel, this heated air is now used over again. This re-use of the air may dry out the air so much that eyes and throats become dry. To avoid dryness, water vapor is added to the air by a *humidifier*. A humidifier is usually a pan of water placed inside the metal jacket surrounding the furnace. It is in this jacket that the air is heated (Fig. 124). The water in the pan is evaporated to add water vapor to the air before it reaches the rooms.

In the hot-air heating system, the warmed air generally travels through large pipes called *ducts*. The ends of these ducts are not attached to radiators but are simply covered with an iron grillwork with holes that can be opened or closed. This cover is called a *register*. The register may be put into the floor, baseboard, or wall. The convection currents (p. 259) produced by the heating of the air in the furnace keep the air circulating. In some homes an electric fan built into the main duct speeds up the circulation of the heated air to increase comfort in the rooms.

Hot-Water Heating

Hot-air heating systems, especially those with fans to circulate the air, can warm the air in a cold house very quickly. But the house cools off fairly fast when the heat is turned off. The advantage of a hot-water heating system is that you can bank the coal furnace early in the evening and for hours still have a warm house. It takes a long time for the hot water in the radiator pipes to cool. Many heating systems have a device called a thermostat, which looks somewhat like a thermometer. What you see is really a kind of thermometer, but it is connected to a small electric switch



124 In a hot-air heating system, the rooms are warmed by convection currents. Cool air flows downward to be heated and at the same time pushes the lighter warm air up into the rooms.

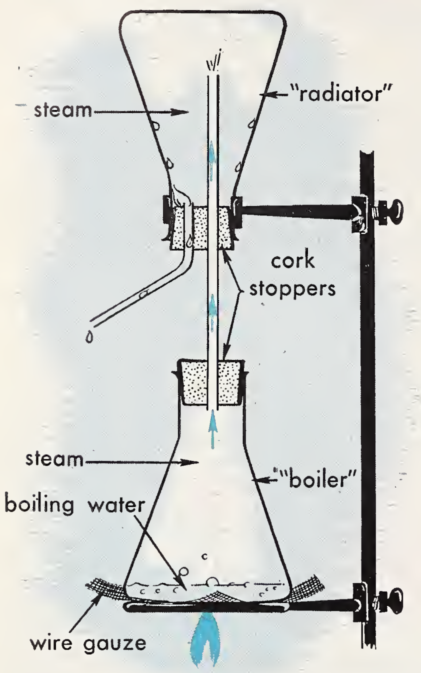
that turns the furnace on when the thermometer goes below a certain reading and turns it off when the thermometer reaches the temperature you want in the room.

Can you see any disadvantage in a hot-water heating system? Suppose you decide to take a two-week vacation in Florida or southern California when the temperature of your house might go below the freezing point of water. What might happen to the pipes of your heating system if you fail to drain out the water? If you do not know the answer, fill a medicine bottle with water, put on the cap, and set the bottle in a tray in the ice cube section of your refrigerator.

Steam Heating Systems

A hot-water heating system is an open-pipe system because it has one pipe leading to an expansion tank. Water expands as it is heated. Therefore this tank allows for the changes of water level caused by the heating of the water. A steam heating system, on the other hand, is a closed-pipe system. This means that the pipe goes to the radiators and back to the furnace. Steam pressure builds up within the pipes. Of course, there are valves on the radiators which can be opened or closed, and there is a safety valve on the boiler. This valve opens automatically if the steam pressure gets

MODEL OF STEAM HEATING SYSTEM



125 *Project:* You will find it easy to set up this glass model steam heating system. Note that you must leave the return pipe open so the pressure of the steam will not become great enough to blow the system apart.

too high. This is true also of hot-water systems. It is impossible in the model of the steam heating system in Fig. 125 to have a valve like this. If you make this model be sure to leave one tube open to the air. Otherwise, the steam pressure may quickly build up and shatter your model with great force. The model is perfectly safe.

Like hot-air systems, steam heating provides a quick method of heating buildings, especially large buildings. If you put your hand on the "radiator" of your model, you will find that it becomes too hot to touch soon after the flame is lighted. Notice, however, how quickly it becomes cool again after the flame has been put out.

Let us now look at how a real steam radiator works. It may have either one or two pipes connecting it to the boiler. If you have steam heating at home, go down to the cellar or basement and see where the pipes connect to the boiler. The boiler is kept only partly filled with water so that the steam can form quickly. The "boiler" may be a set of coils of pipe. The steam fills the riser pipe, which, as its name suggests, lets the steam rise into the radiators (Fig. 126).

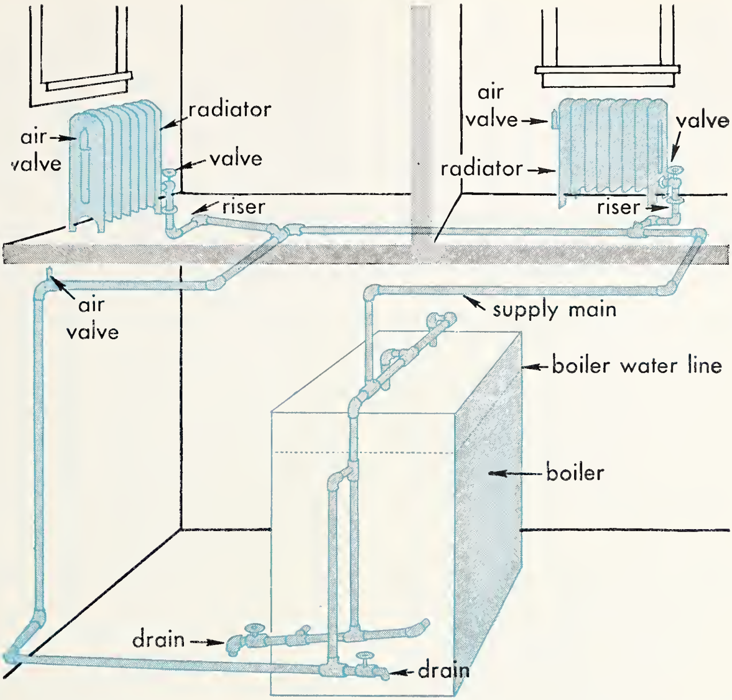
In the radiators, the steam gives up its heat and changes back into water. In a one-pipe system, water runs down inside the riser pipe. In a two-pipe system a second pipe returns the water to the boiler.

All things considered, what kind of heating system is best? To answer that question you will need many facts. There is such a great difference in houses, in climate, in the supply and cost of fuel, and in other costs in our country that no general rules can be stated. However, we can tell you that these are some of the things you will need to consider: first cost, operating cost, convenience, and cleanliness. This is the kind of problem a committee of pupils can investigate. Manufacturers of heating systems will give you information. You can also get some important facts from the U.S. Weather Bureau.

Air-Conditioning Systems

In one way or another, you may solve the problem of heating your home in winter. But what will you do in hot weather? Most people now

STEAM HEATING SYSTEM



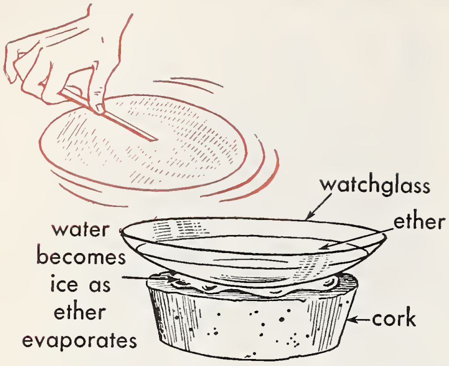
126 In a one-pipe steam heating system, the steam rises to the radiators through the pipe marked "riser" and then condenses as drops of water. These drops run back to the boiler through the same pipe. Why must the apparently horizontal pipes slope a bit? *Project:* Build a model one-pipe steam heating system.

want a system that will give them comfortable indoor weather all year. They want their houses to be properly ventilated at an even temperature (68–70° F.) and kept at about 50% humidity. In short, they want perfect weather at home and in their public buildings.

Indoor weather depends upon what the indoor air is like. Air, as you have learned, carries moisture in the form of water vapor; its temperature is changed by the things it touches; it circulates in convection currents; and it carries odors, germs, and dust. If we can circulate air gently, without drafts, and if we can control the other conditions to our liking, we will have the indoor weather we want for good health and comfort. Such a system is known as complete air conditioning.

Air Conditioning in Every Season

We have seen how heat may be added to air (pp. 260–262), but removing heat from air is a bit of a problem. A simple experiment will show



127 Ice may be made when a refrigerant evaporates quickly. The ether takes so much heat from the watch glass and water that the water freezes. The cork acts as insulation. Do this in a well-ventilated room in which there is no open flame, and with your teacher's permission.

you one way it can be done. You know now that when water evapoates it cools things. Some liquids evaporate more quickly than water and thus cool whatever they touch faster than water does. The liquid you will use will depend upon what your teacher has on hand, but we will suppose it to be Freon. Freon is a chemical that will boil at about −20° F. When it boils, it takes a great deal of heat from anything it touches.

If you put a fresh flower in liquid Freon for a half-minute, the flower will be frozen stiff. You can then break it with your fingers as if it were made of glass. You would not want this to happen to your fingers, so keep them out of the Freon.[1]

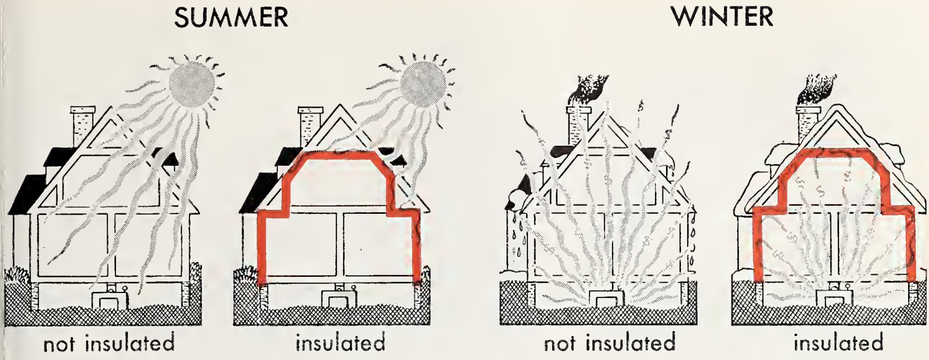
[1] If you cannot get Freon, you can freeze a watch glass to a cork by pouring ether into the watch glass and setting it on a cork wet with a drop or two of pure water. Fan the ether but do not inhale it or have any flame in the room. Ether explodes easily.

Because it takes so much heat from things so quickly, Freon is an excellent *refrigerant.* Refrigerants are chemicals used to keep a refrigerator cold or to cool air in an air-conditioning system. Freon is a safe refrigerant because it will do no one any harm if it should accidentally escape. It will not burn or explode.

To let Freon escape as we did in our experiment with the flower would be costly. In a cooling system, the refrigerant is used over and over again by circulating it in a closed-pipe system. There is another reason for not letting Freon escape. The refrigerant must remain under high pressure in one part of the system and under low pressure in another part. A pump lowers the pressure to make the refrigerant evaporate faster. Then, like the Freon in your experiment, the refrigerant takes heat from whatever is near it.

In some cooling systems a strong solution of salt called *brine* is used. As this brine is pumped through pipes near the refrigerant, it gives up its heat and becomes very cold. It then flows through pipes to a box through which the air to be cooled is passing. This air now gives up much of its heat to the pipes and brine. Finally, the cooled air is blown through ducts to all parts of the building. Then the cooled air circulates in each room.

This cooling process also removes much of the water vapor from the air. If you have ever seen an air conditioner working on a very humid day, you may have noticed that water drips out of it. This water was taken from the air as it passed through the cooling box. Filters of glass wool clean the air as it goes through the box. To get the best results from an



128 In summer a well-insulated house keeps out much of the sun's heat. In winter the heat from the furnace is not lost rapidly. How does insulation save money for the homeowner?

air-conditioning system, the windows of the building should be kept closed. Otherwise hot, dirty, humid air will mix with the conditioned air coming through the cooling system and will make the room hot and sticky. Only the window where the unit is installed should be kept open.

You must watch your windows in winter as well as in summer. In winter poorly fitting windows may let in so much cold air that your home will be chilly and drafty even though you keep the heating system going all the time. The simplest thing to do about loose windows is to put weather strips along the edges of the frame. A storm window — an extra window outside the regular window — is even better if you have wide ranges of temperature and very cold spells. Storm windows help put an air space between themselves and your regular windows. Thus they keep the heat in by insulating your windows.

Insulation Adds Comfort

If you live in your own house and if there is little or no *insulation* in the walls and top floor, you may have had the experience of the people who live in the house with the clean roof (Fig. 129). The snow has been melted by heat that has gone out through the roof. The people next door live in an insulated house. It cost them more to build their house, but it costs them less to live in it. They had to pay for the insulation that is in the walls and roof, but they do not have to pay for fuel that is wasted.

A well-insulated house is like a glove with a fur lining. It has a layer of glass wool, rock wool, or some other material with a lot of air space in it in the gap between the inner and outer walls. The roof or attic is also lined with this insulating material. The air in the insulating material is a poor conductor of heat. It helps to keep the heat you pay for inside the house in winter and the heat you do not want outside the house in summer (Fig. 128).

Simple Weather Protection

Even if you live in a poorly built house or one that is well built but does not have air conditioning, you can do several things to improve your indoor weather. Use the knowledge you have gained in this unit.

JOHNS-MANVILLE

129 *Puzzle:* Why is there no snow on the roof of the house on the left? *Answer:* That house is not well-insulated. Heat escaping through the roof melted the snow. This is a waste of money.

Weather-strip material does not cost much. It comes as strips of felt that can be tacked on or as strips of a substance that looks like putty. It will seal openings around windows or outside doors. To help you avoid a draft, place a piece of board or a glass set at an angle to the bottom of the window to send incoming air upward.

Suppose the air is too dry. You can make your own humidifier, first by putting a pan of water on the stove. You can place some growing green plants in the windows. The water green plants give off through their leaves will help to raise the humidity of the air in your room. You must care for the plants, however, at least by watering them daily. Thus you can help air condition any home at low cost.

SAFETY FROM FIRE

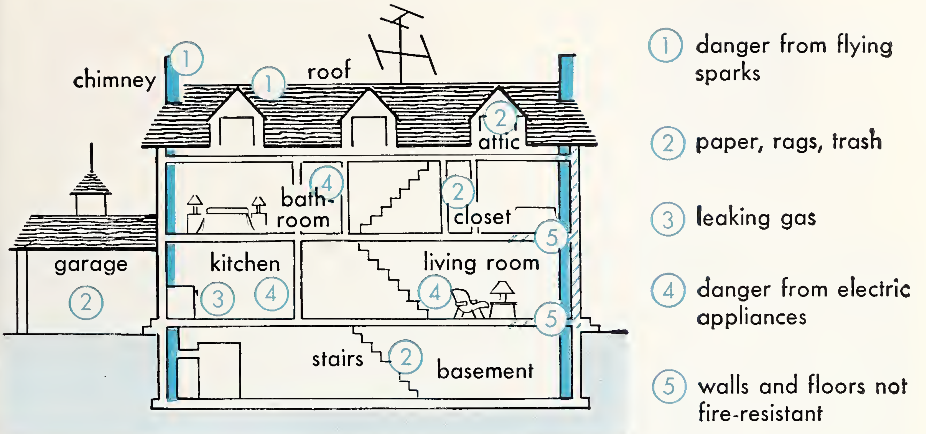
If it is important to make your home a comfortable place in which to live, it is even more important to make it a safe place in which to live. There are many hazards to safety in a house, but the most dangerous is fire. Let us see how fire protection can be built into a house.

Building in Fire Protection

The framework for the walls of houses is usually studs, which are pieces of wood 2 by 4 inches placed upright 12 to 16 inches apart. To the outer side of the studding the boards of the outside wall are nailed. The material of which the inner wall is made is nailed to the inner side of the studs. This leaves an air space between the inside and outside walls. This space may be left empty or filled with insulating material (p. 265). Why will filling this space with a material like rock wool, which will not burn, keep a fire from spreading quickly? Brick or poured concrete fire stops at each floor level also slow or stop the spread of fire from one floor to another.

As good as it is to prevent a fire

FIRE DANGER SPOTS IN THE HOME



130 Draw a plan like this for your home and mark on it any danger spots you may find. Do you find any hidden hazards in your home? If you do, discuss them with your parents and help them to correct each hazard.

from spreading rapidly, it is even better to prevent it from starting. This can be done by getting rid of the fire hazards in your home.

Getting Rid of Fire Hazards

Strange as it may seem, many people burn down their houses while trying to keep the house warm. Of course, they do not mean to do so when they start a fire in a fireplace or furnace. Any fireplace or furnace is supposed to burn fuels safely. However, chimneys, flues, and furnaces may have cracks that need repairs. Sparks from burning fuel may reach parts of the house that will burn. Before a furnace or fireplace is used, chimneys should be inspected, and cleaned if necessary. Sometimes people forget to put a fire screen around a fire in a fireplace, and sparks perhaps pop out on a wooden floor, rugs, or a sofa. These sparks may smolder for some time and then suddenly burst into flame.

Sometimes furnaces and stoves are placed too close to walls that will burn if they become overheated. A sheet of metal placed upright behind the hot stove is helpful. It will carry away enough of the heat and give protection to the walls.

Cleaning cloths, newspapers, and curtains should be kept away from gas heaters, oil burners, electric heaters, and stoves. Matches should be kept out of reach of children. Have you checked all the places in your home where a fire might start or spread quickly? If not, let that be your job for tonight. Do something about any conditions which need correcting.

Fires Which Start Themselves

Sometimes fires start without anyone's lighting them. Such fires are caused by *spontaneous combustion* or spontaneous ignition. In spontaneous combustion, a material suddenly bursts into flame. How does this

happen? The answer lies in knowing the causes of fire.

A fire must have fuel, oxygen, and heat. The fuel may be anything that will burn. The oxygen is in the air. You may think that if there is no flame or heat nearby there cannot be a fire. This is not true. Some things, like damp hay, a pile of damp newspapers, drying paint rags, or oil-soaked rags, combine slowly with the oxygen of the air and in so doing become warm enough to start burning. This slow oxidation is especially dangerous if materials are stored where air does not circulate. The heat of slow oxidation builds up, and the materials start to burn. Carelessness in storing materials of this kind causes much property damage and loss of lives every year.

Putting Out a Fire at Home

Even with the best of care you may be unable to prevent a fire in your home. To be safe, you and your family must be ready to act quickly. If the fire is small, you may be able to put it out before it can spread.

You have learned there are three things a fire needs. And there are three ways to put out a fire. First, you can separate the fuel from the fire. For example, you might throw a burning pillow out of the window so it could not set fire to anything else in the house.

131 For each fire danger there is a safety measure you can take. Discuss each of these dangers and safety measures with your parents. One danger not shown is carelessness. Only you can remove that fire hazard by always being careful and alert.

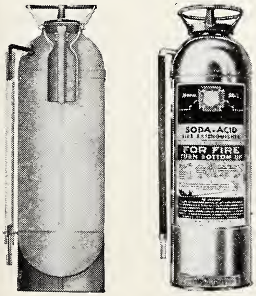
Fire!

GENDREAU

NATIONAL BOARD OF FIRE UNDERWRITERS

132 *Top*, to send a fire alarm just pull down the lever on the outside of the box. A bell will ring, but stand by the box to give the firemen directions to the fire and to the nearest water hydrant. Never tamper with a fire alarm box. *Center*, just one of 340,000 homes destroyed each year by fire. *Bottom*, a soda-acid fire extinguisher, showing contents. Note that in using a fire extinguisher the stream is directed at the base of fire.

AMERICAN–LAFRANCE–FOAMITE CORP.



Second, you can shut off the oxygen supply. This would happen if you dropped a pot cover onto a pan of burning fat. Third, you can lower the temperature of the fuel below its *kindling temperature*. The kindling temperature is the lowest point at which a fuel will burn. Pouring water on most fuels will do this. Water will also shut off the supply of oxygen. To put out a fire you need to do only one of these three things: remove the fuel, remove the oxygen, or lower the temperature. A fire extinguisher does one or more of these things. It is well to have one at home. Keep it where you can easily get at it if you need it.

Fire Extinguishers at School

You may see a pail of sand, an asbestos blanket, or a chemical fire extinguisher in your science room. Do you know why? The sand and the blanket may be used to smother a fire, that is, to shut off the oxygen supply. You should take the blanket out of its holder and practice using it so that you will know what to do if fire breaks out.

The carbon tetrachloride type of fire extinguisher should not be used indoors for demonstration unless you have the windows wide open. The gas that is formed when carbon tetrachloride evaporates is harmful to people. This gas is heavier than air, and so it will settle down around a fire and smother it. The smothering action of the gas makes this kind of extinguisher excellent for putting out fires in electrical machinery, automobiles, and greases.

Many of the larger fire extinguishers in your school are of the soda-acid type (Fig. 132). They get this name from the fact that they contain two main substances: soda, like the baking soda you have in your kitchen; and sulfuric acid. This acid is in the small bottle shown in the cut-away photograph in Fig. 132. When you turn a soda-acid fire extinguisher upside down, the acid pours out of the little bottle and mixes with the soda. At once there is a violent chemical reaction which makes carbon dioxide gas form. The great pressure of this gas pushes the fluid out ahead of it with such force that you can send a stream against a fire 10 to 15 feet away. Sometimes another chemical is mixed with the soda so that a thick foam comes out of the hose. A foam-type extinguisher is very useful in fighting an oil fire because the foam floats on top of the oil like a blanket, keeping the air away from the fuel. Water is heavier than oil and will flow under it and spread an oil fire. It is important to use the right kind of fire extinguisher on different kinds of fires.

There are fire extinguishers which send out a cloud of carbon dioxide gas. Because carbon dioxide is heavier than air, you can pour it into a beaker or glass containing a burning candle and the flame of the candle will be put out.

If you live in a private house, you should own at least two fire extinguishers. A large one should be kept in the cellar. This can be of the soda-acid or foam type. In the kitchen you should have a smaller hand-size carbon dioxide extinguisher. It is very useful if a pan of fat takes fire. It is also safe to use on any fire caused by electricity because there is no liquid to conduct the electricity to your body.

You may think that no fire will ever start in your home. However,

the experts who study the facts and figures of fires tell us that somewhere in America a home is burning every minute of the day and night. A fire extinguisher of the right kind used correctly and quickly may keep your home off this list.

In Case of Fire

Fighting a fire just as it starts is a good thing to do, but saving your life is even more important. In case of fire, you must never risk your life trying to put out the fire. Putting out fires is a job for trained firemen. If your house or your neighbor's house does catch fire, the first thing to do is make sure no one will be trapped inside the house. You cannot hide from fire under a bed or in a closet, as some people have tried to do. You must have a plan that will work without fail.

In school you have fire drills to train you how to get out to safety. When the fire signal sounds, make sure you follow every direction your teacher has given you.

Wherever you are — in school, at home, in a friend's home, in a place of business, restaurant, theater, or other public place — always make a mental note of at least two ways to get out (exits). You may be sure that if there were a fire in school, your teacher would know more than one way to lead you to safety should the stairs or exit nearest your room be blocked by flames or thick smoke.

When a fire starts, you have to act quickly. If you think the fire has too big a start, get out as fast as you can. In your haste do not forget to close every door you can put between yourself and the fire. Remember, hot air rises. Do not go upstairs in a burning building. A lungful of heated air may make you collapse long before the flames reach you. Put in a call by telephone from a neighbor's house or from the nearest fire alarm box. Know in advance where the alarm box is and how it works (Fig. 132). Never pull the lever on a fire alarm box unless you are reporting a fire. It is against the law to turn in false alarms.

You spend a large part of your life inside houses of one kind or another. You will want to be comfortable and safe. This chapter has given you an idea how to do so. Many books have been written on this subject, and you have much more to learn. Keep your eyes open and your mind alert to the things that make a house a home. Then we believe you will have a home that is safe and fit to live in. If it is already a fine place in which to live, do all you can to keep it that way.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words against their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

fiber	central heating system	refrigerant
fabric	humidifier	brine
radiant heating	duct	insulation
convection current	register	spontaneous combustion or ignition
conduction		

1. material which lessens heat loss and is itself a poor conductor
2. a large pipe used in certain types of air-conditioning systems
3. the transfer of heat from molecule to molecule, by direct contact
4. a single strand of material used in making cloth
5. a device for adding moisture to air
6. a covering of a duct which may be opened or closed
7. a type of fire started by the heat resulting from slow oxidation
8. a strong solution of salt
9. a woven cloth
10. a heating system in which all parts of a house are heated from one furnace, which is usually located in the cellar
11. the upward movement of warm air as cooler air moves in under it
12. the transfer of heat by rays
13. a liquid that evaporates so fast that it cools things, as, for example, Freon

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. An open weave in clothing allows for better . . . and therefore better . . . of sweat.
2. The best protection against the wind is provided by garments made of . . . .
3. Black cloth will take in . . . heat from sunlight than white cloth of the same kind.
4. Hands will be cold in tight-fitting gloves because the . . . is poor.
5. Good wall and roof insulation will keep a house . . . in winter and . . . in summer.
6. The three main types of central heating systems are . . . , . . . , and . . . .
7. The ideal indoor temperature is . . . to . . . degrees.
8. The ideal humidity is about . . . %.
9. Fires are sometimes started by the careless disposal of . . . rags.
10. All you have to do to start a soda-acid–type fire extinguisher is to . . . .

GOING FURTHER

In the Laboratory and Field

1. *Cloth and water.* Cut samples of equal size of cloths of many kinds. Be sure each sample was ironed flat and smooth at the start. Dip each for a half-minute into a measured quart of water. Note (*a*) how much water each sample soaked up, (*b*) how long it takes each sample to dry, and (*c*) the smoothness of each sample after drying. What has this to do with protection against rain?

2. *Effect of weather on paints.* Get a dozen or more pieces of unpainted wood of the same size and kind. Paint all but one with one coat of various types of indoor and outdoor paints and varnishes. After the first coat has dried, paint half of each board with a second coat of the same paint. Expose all your samples to the same kind of weather conditions for a month or more and compare them.

3. *Study of building construction.* If a house is being built in your neighborhood, take pictures or draw sketches of it in each stage of development. Have the science reporter of your school or class newspaper interview the builder and ask about the materials the builder is using and how the house is being protected from weather and fire.

Put on Your Thinking Cap

1. List the things you would look for in buying a good suit, dress, or overcoat. Explain why.

2. Find out from your neighbors or a builder the advantages and disadvantages of different types of houses, including the new prefabricated houses. A prefabricated house is one that is made in large sections in a factory so that it can be put together quickly.

Adding to Your Library

1. *Fire in Your Life* by Irving Adler, Day, 1955. What is fire? This book tells you about its history and its use in fuels, engines, and metals.

2. *Miracle Fabrics* by Ellsworth Newcomb and Hugh Kenny, Putnam, 1957. This dramatic story of man-made textiles tells of the search for the perfect synthetic fiber.

3. *How Do You Build a House?* by Margaret and Charles Mason, Sterling, 1953. A complete story of building a house from the ground up.

4. *Houses* by Edward Osmond, Macmillan, 1956. How the English house has developed through the centuries.

A Bit of Research

Draw a picture of the house you live in. On the drawing put a red cross wherever you find a place where a fire may start. Place a black cross wherever you find your house is not weatherproof. Finally, put a blue cross wherever you find that repairs need to be made. Put a circle around each of these crosses when whatever needs to be done has been finished.

Careers for You

There are important kinds of work which may be of interest to you now that you have read this chapter. You may find a career in the clothing trade (*designer*, *tailor*) or building trade (*carpenter*, *contractor*). You may wish to join the *fire department*, or become an *architect*.

UNIT 5

Investigating the Earth's Storehouse

Scientists early thought that new materials could be made only from matter in the earth's crust, in its waters, and in the atmosphere. They had evidence, too, that a certain number of different atoms were the building blocks of matter. Then scientists began to suspect — not so long ago — that unlimited sources of energy rested inside the atom. If only there were some way to unlock this energy! The break-through came on December 2, 1942, when it was demonstrated beyond doubt that it was practical to split atoms. Ten years later hydrogen atoms were combined. The result — the wild explosive energy of atomic and hydrogen bombs. But today this wild energy is being tamed for peaceful purposes. In the illustration a scientist working with a nuclear accelerator is searching for new ways to obtain and use atomic energy.

This unit is the story of man's search for new materials and new sources of energy from the atoms in the earth's vast storehouse of matter.

Your Science Inventory

How much do you already know about the earth's storehouse? Copy the following questions in your notebook and write your best answers for each one. When you have read this unit, check your answers to see how many you had right.

1 Sugar is a compound made up of atoms of carbon, hydrogen, and (a) nitrogen, (b) oxygen, (c) sodium, (d) sulfur.

2 By using electricity a chemist can separate water into (a) a gas and a liquid, (b) two gases, (c) two liquids, (d) several liquids.

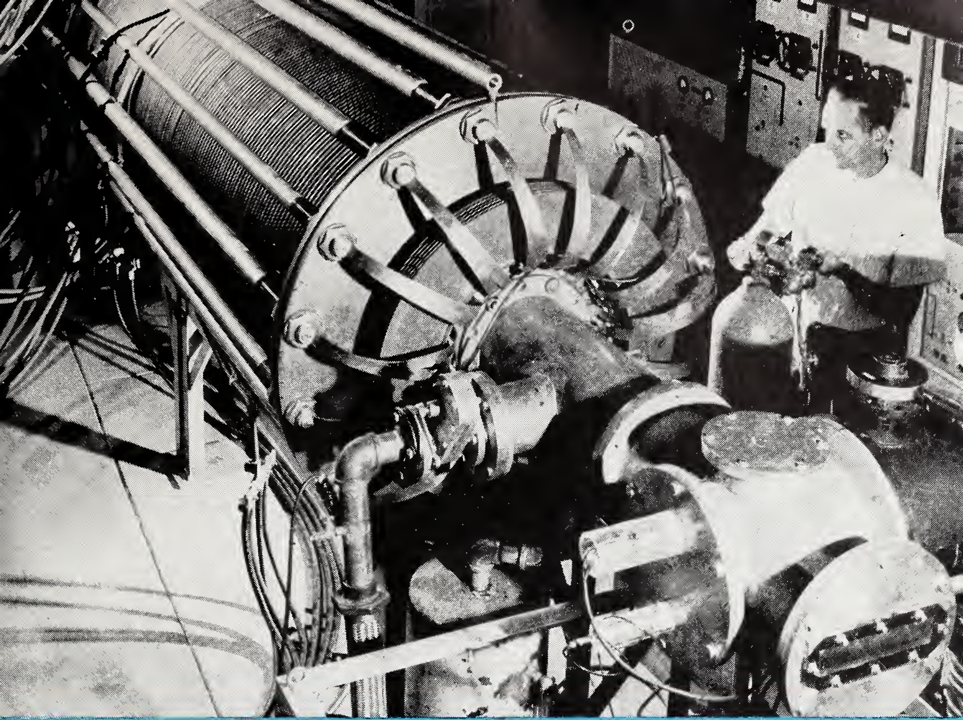
3 The smallest particle known is the (a) atom, (b) electron, (c) neutron, (d) proton.

4 An element unknown until it was made by scientists is (a) helium, (b) plutonium, (c) radium, (d) uranium.

5 If you use a Geiger counter, you will hear clicks in the background. These are caused by (a) cosmic rays, (b) radium-treated watch dials, (c) X rays, (d) atomic explosions.

6 When a hydrogen bomb explodes, (a) all the atoms are destroyed, (b) helium atoms fuse to produce hydrogen, (c) hydrogen atoms fuse to produce helium, (d) only energy is produced.

7 A Geiger counter measures (a) chemical change, (b) combustion, (c) oxidation, (d) radiation.



8 To measure the activity of the thyroid gland a doctor would need a Geiger counter and radioactive (a) cobalt, (b) carbon, (c) iodine, (d) phosphorus.

9 More carbon dioxide will dissolve in a liquid like ginger ale if the temperature is (a) a little above freezing, (b) boiling, (c) 80° F., (d) 100° F.

10 Stainless steel is made by melting (a) iron ores, (b) steel ores, (c) steel with copper and tin, (d) steel with nickel and chromium.

11 You can dissolve the largest amount of soap in (a) distilled water, (b) Epsom salts solution, (c) limewater, (d) salt water.

12 Heating soft coal in a test tube will produce all these products *except* (a) coal tar, (b) coke, (c) charcoal, (d) gas that will burn.

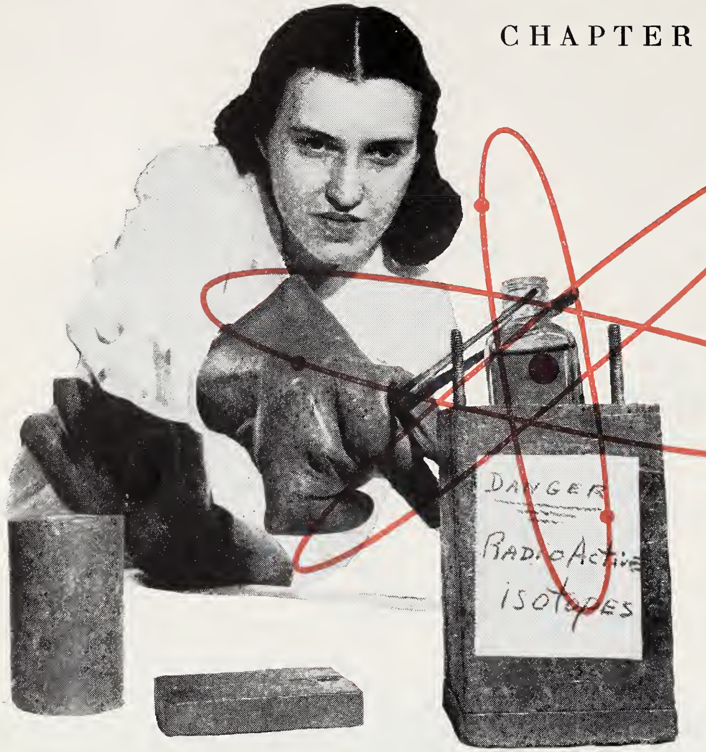
13 Red litmus paper turns blue when it is moistened with (a) lemon juice, (b) soap suds, (c) vinegar, (d) water.

14 The metal that will melt first when heated over a Bunsen burner is (a) aluminum, (b) copper, (c) lead, (d) tin.

15 Cement is a mixture of clay and (a) concrete, (b) gravel, (c) sand, (d) sulfur.

CHAPTER 14

Atoms — Building Blocks of the Universe



A long time ago, man discovered fire. It made life easier, but only when it was used wisely. This is the age of the atom. Today man, as scientist, is studying the make-up of the atom — to use it wisely.

"Suppose I cut a piece of gold wire into two equal pieces. Then I divide one, and keep on dividing each half-piece of wire. There must come a time when I can divide the gold no more, no matter what tool I use. I will have reached the smallest bit of gold that could possibly exist. Of course it would be too small to see."

This was the thought of a man who lived about 2,400 years ago in Greece. His name was Democritus (deh-MOK-rih-tus). He was one of the many great thinkers in Greece at that time. He said that everything — living as well as nonliving — was made up of tiny bits of matter. Democritus gave the name *atoms* to these tiny bits.

Democritus in his thinking about atoms was dealing not with gold alone. He was also dealing with everyday stuff — the stuff you see all around you every moment of your life. Scientists call this stuff *matter*. All things are made up of matter.

In this chapter, you will learn what matter is and how scientists since the

time of Democritus have studied it. You will find that in their studies of matter scientists have discovered things which have changed your way of living. Let us look into these discoveries.

MATTER — ALL AROUND YOU

To test your ability to observe, examine any object on your desk or in the room. It may be a book, an eraser, a ruler, or a pen. After looking at it carefully, write on a piece of paper everything you can think of that will really describe the object. This is not an easy task by any means. A trained scientist describes materials under many headings, such as:

Color
Size
Shape
Luster (dull or shiny)
Hardness
Weight
Solubility (ability to dissolve in water)
Ability to burn
Kind of matter

Now go back to your list. How have you described your object? Examine a different object, like a penny or another coin. Describe it. Now let us go further.

Matter in All Forms

If you examined your two objects carefully, you may have noticed they were alike in some ways and different in others. But at least each had weight. All matter has weight. Did they also have a definite size and shape? All matter that has a definite size and a shape is classed as *solid.* "But," you say, "not all matter is solid." You are certainly right.

Take a piece of ice, frozen water, a solid. It has a definite size and shape and it has weight. Now put the piece of ice into a beaker and heat it. The size and shape of the ice change as it melts. What is the shape of the water? Continue heating. What happens to water when it boils?

By these simple acts you have checked several important facts. You have seen that water, a *liquid*, takes the shape of the container in which it is placed. You know it has weight because the beaker is heavier with water in it than it is when empty. You have seen that boiling water turns into a different kind of matter: steam, a *gas.* A gas spreads evenly through any container in which it is placed. That is why you get just as much air in one corner of a room as in another. That is why, when you pump up your bicycle tire, you do not expect the air to remain in one part of the tire. A gas also has weight; a truck tire when blown up may weigh as much as 25 pounds more than when it is flat.

You know now that matter is found in three forms, solids, liquids, and gases, as shown in the box on the next page.

Can you think of anything, anywhere, that is not a solid, a liquid, or a gas? What is rock? air? water? wood? even the sun and stars?

Make a list of things around you that you see or use at home, on the way to school, or at play. Now let us

see if you can observe the *properties* of each, that is, the things that help you describe it and recognize it. Suppose you were to examine a pebble.

A Pebble	*Its Properties*
Color	Brown
Size	Small
Shape	Round
Luster	Dull
Hardness	Harder than glass
Weight	1 ounce
Solubility	None
Ability to burn	None
Kind of matter	Solid

Do the same for a piece of glass, a can, a penny, water, and air.

You may find that you have to think carefully about some of the things in your list. But you will find that everything on the list is either a solid, a liquid, or a gas.

Three Forms of Matter

1. A solid has a definite size and shape and has weight.

2. A liquid takes the shape of its container and has weight.

3. A gas spreads evenly through its container and has weight.

Now let us look further into what matter is. What are the solids, gases, or liquids you examined made of? Chemicals, you would say. True. But what are chemicals made of?

ELEMENTS ABOUT YOU

You could say your penny is made up of a chemical. Suppose your penny, the one you examined before, were made of pure copper.[1] Your penny would then be made up of the *element* copper. An element is simply a substance which cannot be divided into any other substances by ordinary means. Pure gold is made up of the element gold. The gas oxygen is made up of the element oxygen.

How many elements do you know? Copper, gold, hydrogen, zinc, oxygen? Any others? Table 10 on p. 317 gives you the common elements on this earth.

What is an element made of? An element is made up of its own kind of atoms. Thus the smallest part of the element gold which is still gold is an *atom* of gold. The smallest part of the element oxygen which is still oxygen is an atom of oxygen.

What happens when certain elements join together, that is, when two chemicals combine? Or, put another way, what happens when the atoms of elements combine? Chemists know that the substance formed is entirely different from the atoms which joined to make up the substance. The substance formed is made up of two or more kinds of atoms and is called a *compound*. Most of the materials you use or see every day are compounds. For example, common table salt is made up of the elements sodium and chlorine. Sodium is a metal dangerous to touch. Chlorine is a greenish-yellow poisonous gas. But table salt, a compound, does not hurt your tongue, nor does it give off a poisonous greenish-yellow gas.

Sugar is a compound made up of carbon, hydrogen, and oxygen. None of these elements, tasted or breathed separately or together, would be sugar. Likewise, the water you drink

[1] A copper penny is actually made up of 95% copper and 5% zinc and tin.

is made up of two gases, hydrogen and oxygen. If you breathed both gases together, would they satisfy your thirst?

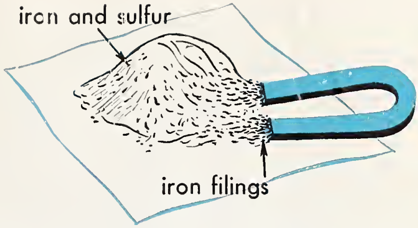
Clearly, some change takes place when elements form compounds. This change makes a compound very different from the elements that are in it. Don't think, however, that compounds are the same as mixtures. They are entirely different one from the other.

Mixtures and Compounds

Place a teaspoonful of powdered sulfur and about two-thirds of a teaspoonful of iron filings on a piece of paper. Mix the iron filings and the yellow sulfur thoroughly. You will find that when you hold a magnet close to the mixture, some of the iron filings hold onto the magnet. The yellow sulfur does not. You see by this that two or more substances in a *mixture* can often be separated one from the other (Fig. 133).

What is the difference between a mixture and a compound? The substances in a mixture have not combined with each other to form a new substance. As in your experiment above, the substances in a mixture may be separated from each other. A compound is a new substance different from the substances from which it was originally made.

You can make a compound. Place the mixture of iron filings and sulfur in a test tube and heat over the hot flame of a Bunsen burner. You will notice that the sulfur melts and then the mixture glows. Remove the tube from the flame, and after the tube has cooled break it open

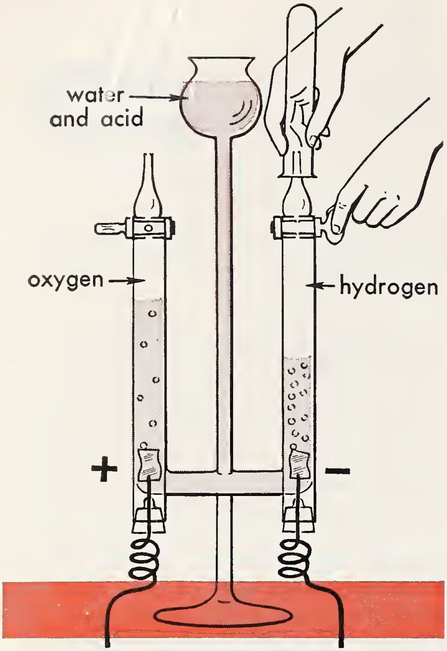


133 A mixture of iron filings and sulfur (and a magnet). How is the iron separated from the sulfur?

by tapping the lower end sharply with a hammer. Now you will see that the substance inside the tube no longer looks like either sulfur or the iron filings. When you hold the magnet close to the substance, are iron filings attracted to the magnet? No! You no longer have a mixture of iron and sulfur, but instead a compound made up of iron and sulfur. It is called iron sulfide. It is different from the mixture of iron and sulfur you heated. It has new properties. The two elements iron and sulfur are now combined chemically into a new substance, iron sulfide.

Mixtures are found everywhere. You have learned that only a few elements are found in nature the way gold is found. Usually they are found combined with other elements in compounds. And most compounds are found mixed with other compounds in the earth's crust.

The water you drink is not absolutely pure; it has in it small amounts of the substances found in the earth. Sea water has in it larger amounts of these substances than does fresh water, so that it is not healthful to drink. The air you breathe is a mixture of gases; in it are found nitrogen, oxygen (both elements), and carbon dioxide and water vapor



134 An electric current breaks up water (to which a little acid has been added) into two gases, hydrogen and oxygen. How does the volume of hydrogen produced compare with that of oxygen?

(compounds).[1] Most solids, liquids, and gases found on the earth are therefore made up of mixtures of compounds and elements.

Elements and Molecules

Suppose you were to divide some matter, like a cupful of water, into the smallest part which would still be water. What would you have? You would have a *molecule* of water — not atoms of water, as Democritus thought. Let us see why you would have molecules and not atoms. First, what is a molecule?

[1] Also in air are small amounts of other elements that are gases, such as argon and neon.

You must have heard the word *molecule* often — as often as you have heard the word *atom*, perhaps. A molecule is the smallest part of any material or substance that really is that substance. Thus the *smallest* particle of rubber that has the properties of rubber is a molecule of rubber. The *smallest* particle of salt that has the properties of salt is a molecule of salt. The smallest particle of carbon dioxide that has the properties of carbon dioxide is a molecule of carbon dioxide. Molecules cannot be seen with the naked eye or even with ordinary microscopes. However, some very large ones have been seen with the powerful electron microscope.

Molecules are made up of atoms. How is a molecule different from an atom? To see this you will need to do some experiments.

Breaking Up Molecules

Molecules of some substances can be broken up by heating. Heating speeds up the movement of the molecules, causing them to strike together with a force great enough to break them up into atoms. Thus mercuric oxide, made up of mercury and oxygen, will break up into mercury and oxygen when heated. You can do this in your school laboratory (p. 288).

Molecules can also be broken up by electricity. Let us see what happens to water molecules when electricity passes through water.

Your school laboratory probably has a piece of apparatus like that in Fig. 134. Fill the apparatus with water to which has been added a little sulfuric acid. Connect the apparatus to two to four dry cells, as in Fig. 134.

Notice the bubbles of gas rising in each tube. In one of the tubes, however, the level of water is falling twice as fast as in the other. A gas is collecting in each tube as the electricity breaks up the molecules of water. What gases are to be found in each tube? Let us test them.

Hold a test tube over the tube which has more gas. Open the end of the tube. The gas rushes upward into the test tube. Test this gas with a burning splint of wood. A small explosion takes place; you hear a small "pop." When flame touches a mixture of hydrogen and air, the mixture explodes. Since you know that water is made up of hydrogen and oxygen, you conclude that the tube with more gas in it (the one with the lower water level) had hydrogen in it.

Now collect the gas in the other tube and test it with a glowing splint of wood. The splint bursts into flame. A splint burns brightly in pure oxygen much better than it does in air. Air, you remember, contains only 20% oxygen. Since one of the elements in water is oxygen, you conclude that the tube with the higher water level contained oxygen.

Here is what you might further conclude:

1. The amount of the hydrogen formed from breaking up water molecules is twice the amount of the oxygen formed. You know this because the water level in the hydrogen tube fell twice as far in the same time as the level of water in the oxygen tube. Therefore, water contains twice as much hydrogen as oxygen by *volume*, that is, by the amount of space it takes up.

2. Since the smallest particle of water is a molecule, a molecule of water is made up of twice as much hydrogen as oxygen.

3. You know now that molecules are made up of atoms. Therefore you would finally conclude that each molecule of water must contain at least two atoms of hydrogen and one atom of oxygen. Thus, when an electric current is passed through water, each molecule breaks up in this way until all the water is used up:

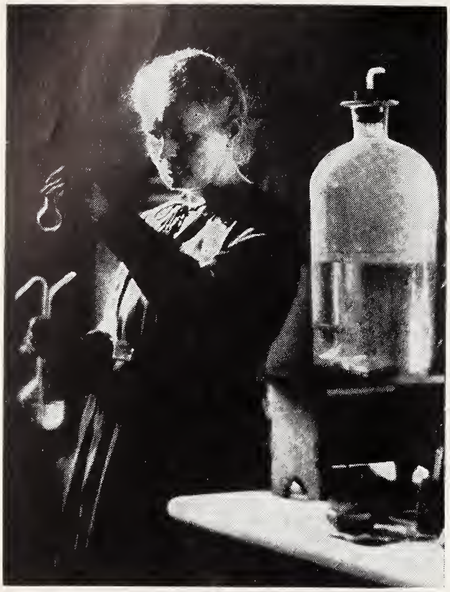
1 molecule of water	→	2 atoms of hydrogen	+	1 atom of oxygen
1 molecule of water	→	2 atoms of hydrogen	+	1 atom of oxygen

You can see now why water is called H_2O. Writing H_2O is the simplest way to show that there are two hydrogen atoms and one oxygen atom in a molecule of water.

When we change molecules of water or any other substance into their separate atoms, or unite atoms to form molecules, we have a *chemical change*. This is different from a physical change, in which just a change in the appearance of the material is made. Tearing a piece of paper or changing ice to water or water to steam are examples of physical change.

BUILDING UP THE UNIVERSE

Everything on earth which we have examined — and scientists think that the entire earth, the entire universe



KEYSTONE

135 Madame Marie Curie, discoverer of radium, started scientists on the trail of other radioactive elements.

— is made up of elements, compounds, or mixtures of elements and compounds. You cannot name anything that is not made up in this way. At this point study the following diagram. (The arrows should be read to mean "are made up of.")

earth and universe	→	elements and compounds or their mixtures	→	molecules made up of atoms

In a way, atoms are the building blocks of the universe. That is, the universe is made up of atoms.

The Roll Call of Atoms

An element, as you have seen, is a substance which with other elements can make up compounds. Compounds, elements, or their mixtures are the solids, liquids, or gases that make up the earth and universe. All these elements which make up compounds or mixtures are made up of atoms.

How many types of atoms have scientists discovered? Before 1940, we could say that we knew of 92 elements, made up of atoms, on earth. However, as work on atomic energy went on, scientists actually made ten new atoms. Later you will learn how this great discovery, a method for making new atoms, came about. Right now you need to know only that man can make new atoms and that he has actually made ten of them.[1]

The evidence to date shows that there are 102 kinds of atoms, making up 102 different elements.

ATOMS INTO SMALLER PARTICLES

Now let's go back to Democritus. You remember his idea — that the smallest particle of a substance is an atom. It took over 2,300 years after Democritus died for anyone to give any real thought to the make-up of atoms. By that time scientists had begun to gather some facts upon which to base their thinking.

[1] The ten new atoms are neptunium (nep-TYOO-nee-um), plutonium (ploo-TOH-nee-um), curium (KYOOR-ee-um), americium (am-uh-RISH-ee-um), berkelium (ber-KEEL-ee-um), californium (kal-uh-FOR-nee-um), einsteinium (eyne-STYNE-ee-um), fermium (FAYR-mee-um), mendelevium (men-del-EEV-ee-um), and nobelium (no-BEL-ee-um). The first is named after the planet Neptune; the second, after Pluto; the third, for Madame Curie, the famous Polish scientist (Fig. 135); the fourth, for America; the fifth, for Berkeley, Calif.; and the sixth, for the state of California. The last four are named after scientists.

Dalton and His Atoms

In the nineteenth century, a great English scientist, John Dalton, published his atomic theory. He said:

1. Atoms are very small.
2. Atoms of the same element weigh the same. They are different in weight from atoms of any other element.
3. Atoms of one element can combine with atoms of another element. When they do this, they form new substances.

It is true that these statements seem very simple. Yet Dalton was the first scientist to speak of the weight of atoms. He was also the first to say that atoms of different elements have different weights. These differences in weights are shown by numbers. If an atom of hydrogen, the lightest element, is given the weight of 1, an atom of uranium, 238 times heavier than an atom of hydrogen, is given the weight of 238. When we speak later of carbon 12, we shall mean that an atom of carbon 12 is 12 times as heavy as a hydrogen atom. We shall use, therefore, the numbers 238 and 12 to mean the weights of atoms of uranium and carbon. When we speak here of *atomic weight*, we shall mean the weight of one atom of an element.[1] (See Table 10 on p. 317.)

Taking the Atom Apart

Still Dalton had not gone much further than Democritus. Their idea of atoms was the same. Both men thought atoms were like very tiny marbles that could not be seen.

In later years, scientists went ahead faster. In 1898 came the discovery of radium by Madame Curie. A few years later, it was discovered that atoms of radium threw off particles and rays that went through flesh and even metal. Several different types of particles and rays were discovered. Among them, scientists found *electrons* (eh-LEK-tronz).[1]

You can well imagine what this discovery did to the idea that atoms are tiny, *solid particles* like invisible marbles. Since an atom of radium was found to throw off electrons (particles of matter smaller than an atom) there must be electrons in atoms!

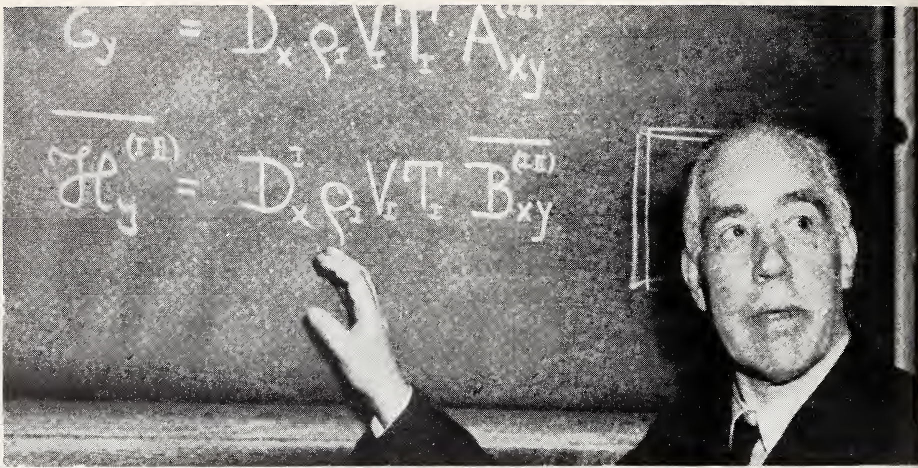
Surprises were not over. Scientists knew now what to look for, and they found that atoms of other elements heavier than radium — yes, even uranium — also threw off particles. A name was needed for the strange kind of activity in which these elements threw off smaller particles and rays. Scientists called it *radioactivity*. From studying radioactive elements, scientists came to have a new and different idea of the atom.

Finding the Nucleus of the Atom

Ernest Rutherford, another English scientist, took up the search. He held the hypothesis, as did Niels Bohr (Fig. 136), a Danish scientist, that an atom is like a very small solar system. A hypothesis, you will remember, is a good scientific guess, or working idea, based on known facts. They supposed that the nucleus

[1] Actually, chemists use the weight of the atom of oxygen as the weight to which other other atomic weights are compared. An atom of oxygen is about 16 times the weight of an atom of hydrogen. Since in this text we are using atomic weights in round numbers, we will use hydrogen as the base for comparison.

[1] Electrons are tiny atomic particles carrying a negative charge.



WIDE WORLD

136 The work of the Dane, Niels Bohr, dealt deeply with the structure of the atom. He did much to show the part electrons play.

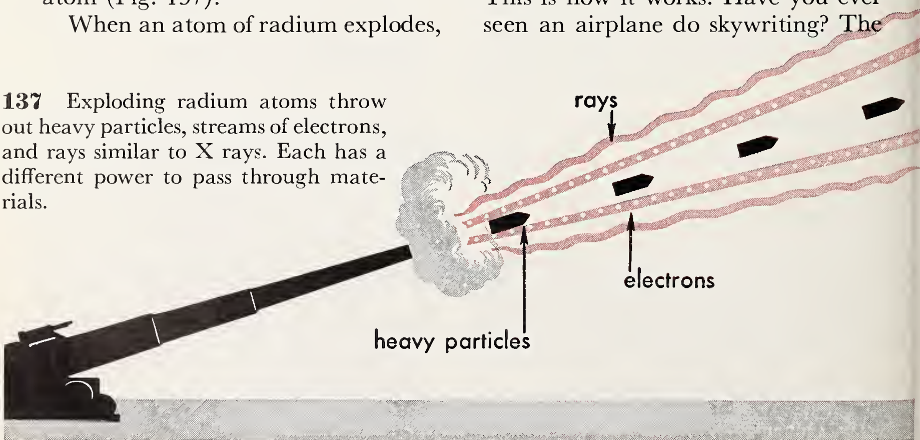
(center) is like the sun, and that the electrons, like the planets, move about the nucleus.

This hypothesis was based on a few known facts, but many other facts were not known. Would the hypothesis fit new facts to be discovered later? It was important to get new facts to check whether the hypothesis was right. Rutherford had the brilliant idea of using radium as a gun in his hunt for more facts about the atom (Fig. 137).

When an atom of radium explodes, certain other particles are given off along with the electrons (Fig. 137). Certain of these particles, much heavier than electrons, have a weight similar to atoms of a gas called helium. These helium particles Rutherford thought of as bullets. Helium particles travel 20,000 times faster than the fastest machine gun bullets! How could he trace their paths?

Nowadays scientists use an instrument called a Wilson *cloud chamber*. This is how it works. Have you ever seen an airplane do skywriting? The

137 Exploding radium atoms throw out heavy particles, streams of electrons, and rays similar to X rays. Each has a different power to pass through materials.



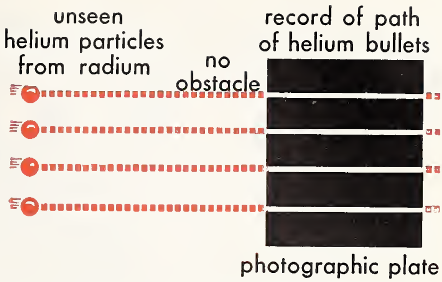
airplane traces its path by giving off a cloud of smoky material. If you could not see the airplane, you would still know it was there by the path it had traced. In much the same way, helium bullets trace a path in the moist air of a cloud chamber (Fig. 138). Rutherford used the cloud chamber in his experiments. He may even have used other methods too complex to be described here. In any event, Rutherford could follow the paths of his invisible helium bullets.

What Rutherford did was to place some tin foil in the paths of these helium particles he was using as bullets. If one of these bullets hit part of an atom in the tin foil, the path of the bullet would be changed, much as a real bullet glances off a hard object. If the bullet did not hit part of an atom, its path would not change.

To Rutherford's surprise, most of his helium bullets hit nothing. They passed through the tin foil as though the tin foil were not there (Fig. 139).

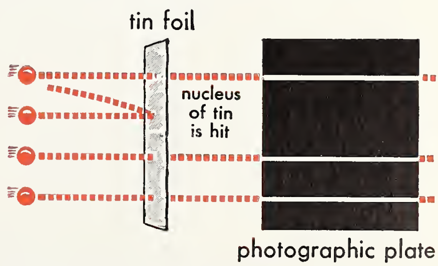
From his work and that of other experimenters, Rutherford built up this picture of an atom: An atom is made up of a tiny center, or *nucleus*, with electrons moving around it. These electrons move around the nucleus of the atom much as our planets move around the sun. Most of the helium bullets passed right through the tin foil because they went through the spaces between the nucleus and electrons of the atoms of tin.

Imagine that it was something like this: Suppose an atom of tin could be enlarged to fill your school playground. The nucleus of the atom would then be as large as a grain of wheat. Standing off to one side of the playground, how many times could you hit the grain of wheat in the middle of the playground with an air rifle? Once in a thousand shots? A hundred thousand shots? This will give you an idea of how hard it is to hit the nucleus of an atom. Remember, however, that under actual conditions the helium bullets used are even smaller than the nucleus of the atoms at which they are fired.

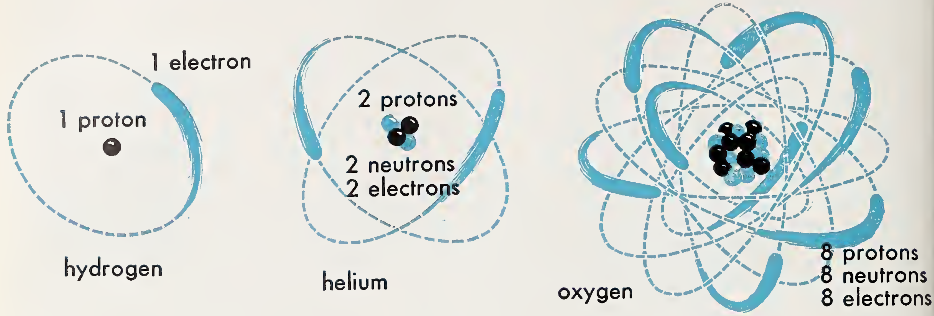


138 The paths of unseen helium bullets can be photographed.

Thus Rutherford concluded that, small as it is, an atom is mostly empty space, with a nucleus at its center. It is now known that if the nucleus of an atom of iron, for example, could be enlarged to the size of an orange, the electrons that move around it would move in circles 45 miles in diameter, that is, about 22½ miles from the nucleus. What an empty space between the nucleus and the electrons!



139 When the nucleus of an atom of tin is hit, the path of the helium bullet is changed. Thus the path does not show on the photographic plate.



140 *Left*, an atom of ordinary hydrogen is made up of one electron rotating about one proton (in the nucleus). Remember that these are not actual size. *Center*, an atom of helium is made up to two electrons rotating about two protons and two neutrons in the nucleus. *Right*, an atom of oxygen is made up of eight electrons rotating about eight protons and eight neutrons in the nucleus.

Exploring the Nucleus of the Atom

Meanwhile, many other scientists were working on the nucleus to find out more about what an atom is made of. They discovered that the nucleus had in it small particles of matter. These they named *protons* (PROH-tonz). They reasoned that the lightest element known — hydrogen — would have the smallest number of protons in its nucleus and the smallest number of electrons outside. The hydrogen atom is now known to have one proton and one electron. Now you see how easy it is to diagram an atom of hydrogen (Fig. 140). Of course, this is not the way an atom of hydrogen really looks. We really do not know how one looks, or how atoms of elements heavier than hydrogen look. This is just a simple way of diagramming atoms to help you picture them in your mind.

In 1932, James Chadwick, who followed Rutherford's experiments, discovered another particle in the nucleus of the atom. He called it a *neutron* (NOO-tron). It weighs almost the same as a proton. Each neutron and proton in the nucleus of an atom is 1,840 times heavier than an electron outside the nucleus. Today scientists know that nearly the entire weight of the atom is in the tiny nucleus.

THE ATOM TODAY

Here is the atom as we know it today, so small that one can hardly picture its size. It would take 250 million atoms of hydrogen placed side by side to make a line 1 inch long. No one has ever seen an atom, not even with the electron microscope. But the unending research of modern science has shown what is inside an atom. To be able to picture an atom of hydrogen, as you have done with the help of this chapter, is something that scientists one hundred years ago would have envied. You now have a good idea of what atoms have in them. You know what is meant by the statement that atoms are the building blocks of the universe. We may ex-

earth and the universe	→	solids, liquids, gases	→	elements, compounds, or their mixtures	→	atoms (of elements)	→	protons and neutrons (in the nucleus) and outer electrons

press our ideas as shown in the box on this page. Again, read each arrow to mean "are made up of."

Whether you look at your clothing, your pencil, the chocolate you eat, or your home, you are looking at combinations of atoms. They are either in the form of elements or compounds, or mixtures of elements and compounds. Look up at the moon, at the planets, at the sun, at the stars. They too are made up of atoms, elements, and compounds. The atom, truly, is the building block of the universe.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words against their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

matter	mixture	physical change
gas	solubility	cloud chamber
liquid	radium	nucleus
solid	radioactivity	proton
atom	chemical change	neutron
element	atomic weight	electron
compound	molecule	

1. a substance in which two or more elements are combined chemically
2. has definite size and shape and has weight
3. stuff you see around you every moment of your life
4. particles of matter in the nucleus of an atom
5. an element whose atoms continually explode, giving off particles and rays
6. the tiny center of an atom
7. a change in which molecules are broken up or made
8. a tiny particle that revolves around the nucleus of an atom
9. the kind of activity possessed by exploding atoms, when particles and rays are given off
10. a change in which the molecules of a substance remain the same
11. spreads evenly throughout its container and has weight

12. the smallest particle of an element which is that element
13. ability to dissolve in water
14. the smallest particle of a substance which has the properties of that substance
15. an instrument for tracing the path of radioactive particles
16. contains substances that have not combined with each other by a chemical change
17. the weight of an atom of an element
18. takes the shape of its container and has weight
19. a substance that cannot be divided into any other substance by ordinary means

Test Yourself

Below are a number of statements, each one of which is either true (based on evidence) or untrue (not based on evidence). In your notebook, mark those which are true with the statement "based on evidence," and those which are not true "not based on evidence." DO NOT MARK THIS BOOK.

1. All matter is made up of solids or liquids or gases.
2. A gas has a definite size and shape, but no weight.
3. Changing water into steam is a physical change.
4. A mixture is different from a compound because it is made by a chemical change.
5. A substance is a solid, liquid, or gas because of its temperature.
6. The energy of electricity can be used to separate water into two parts of oxygen and one part of hydrogen by volume.
7. The ability of radium to give off particles proved that Dalton's idea of the atom was correct.
8. All the electrons in an atom are found in the nucleus.
9. Most of the weight of an atom is in the electrons.
10. A hydrogen atom is heavier than an atom of uranium.

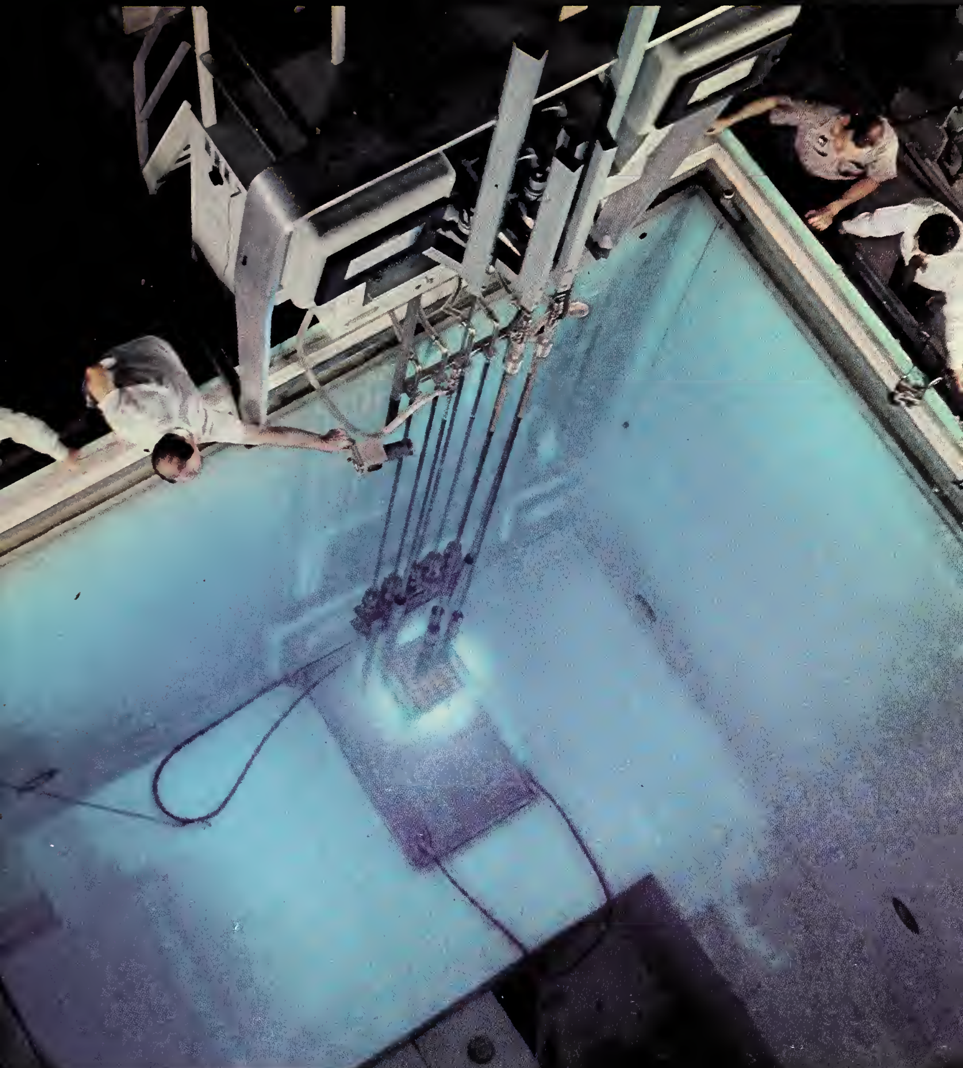
GOING FURTHER

In the Laboratory

1. *Heating metal.* Heat a piece of copper wire in a low gas flame for two minutes. Examine the coating on the wire when it cools. What color is it? Is it different from the copper you heated? Many metals when heated in air combine with the oxygen of the air. For instance, when mercury is heated it combines with oxygen. Now go on to *2.*

2. *Breaking up a compound.* Fill a test tube one-third full of mercuric oxide. Place a stopper and delivery tube in the mouth of the test tube. Heat the test tube in a high flame for five minutes. Collect the gas coming from the mercuric oxide in an empty test tube. Test the gas with a glowing splint. Is it the same gas you tested in the breaking up of water (pp. 280–281)? Now examine

ATOMIC ENERGY



The core of a "swimming pool" reactor in which water is the moderator. The blue glow is created by the fission of uranium fuel. (Photo by Union Carbide Co.)

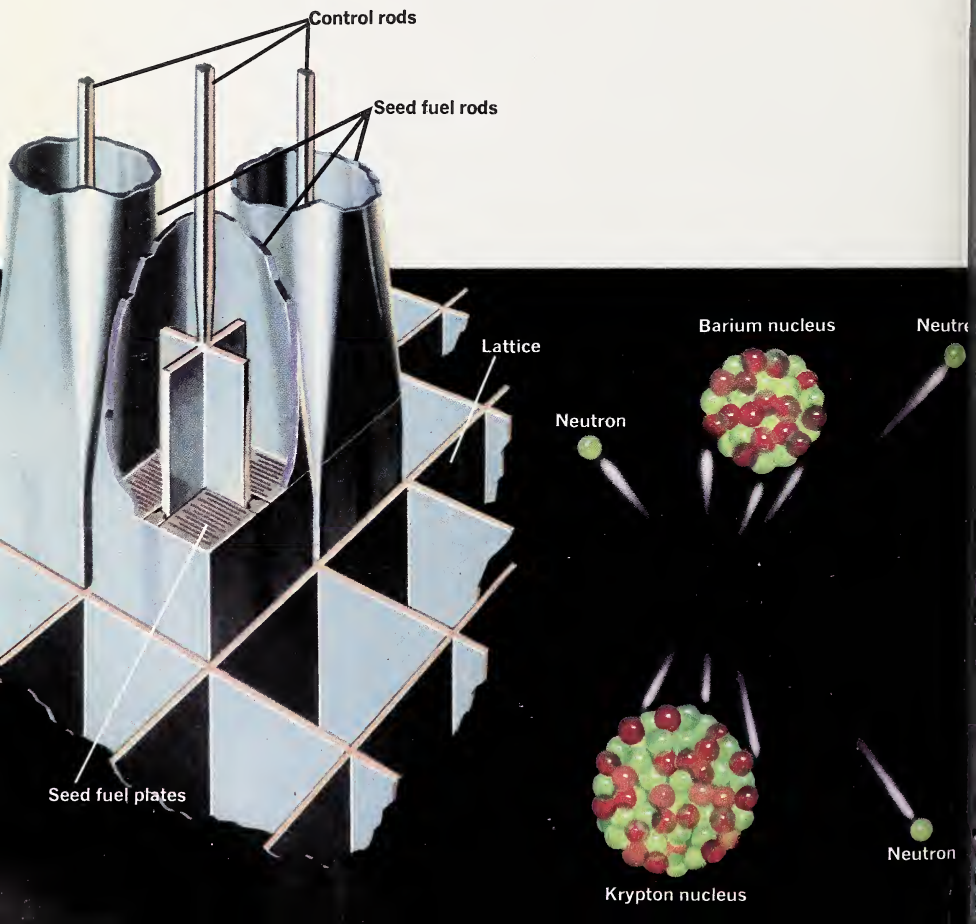
Artwork by CARU Studios, Inc., New York City.
Special acknowledgment is made to the Duquesne Light Company of Pittsburgh, Pennsylvania, and to the Westinghouse Corporation and the U.S. Atomic Energy Commission, for blueprints, technical drawings, and photographs of the Shippingport Atomic Power Station. Further acknowledgment is made to Mr. E. M. Parrish, General Superintendent of the Power Station's Department of the Duquesne Light Company, for continuous advice and assistance which made possible the pictorial diagram of the Shippingport installations.

PRINTED IN THE UNITED STATES OF AMERICA

CONTROLLING ENERGY RELEASE Atomic energy is obtained by bombarding atoms of *uranium 235* (U^{235}) with *neutrons* from the nuclei of other atoms. When a speeding neutron scores a direct hit on the nucleus of an atom of U^{235}, the nucleus splits into two or more smaller nuclei, such as those of the elements *krypton* and *barium*. This splitting (fission) releases an extraordinary amount of energy and sets free several more neutrons. Under uncontrolled conditions, these neutrons can set off a "chain reaction" that rapidly fissions all the U^{235} available, and releases so much heat so suddenly that a tremendous explosion occurs.

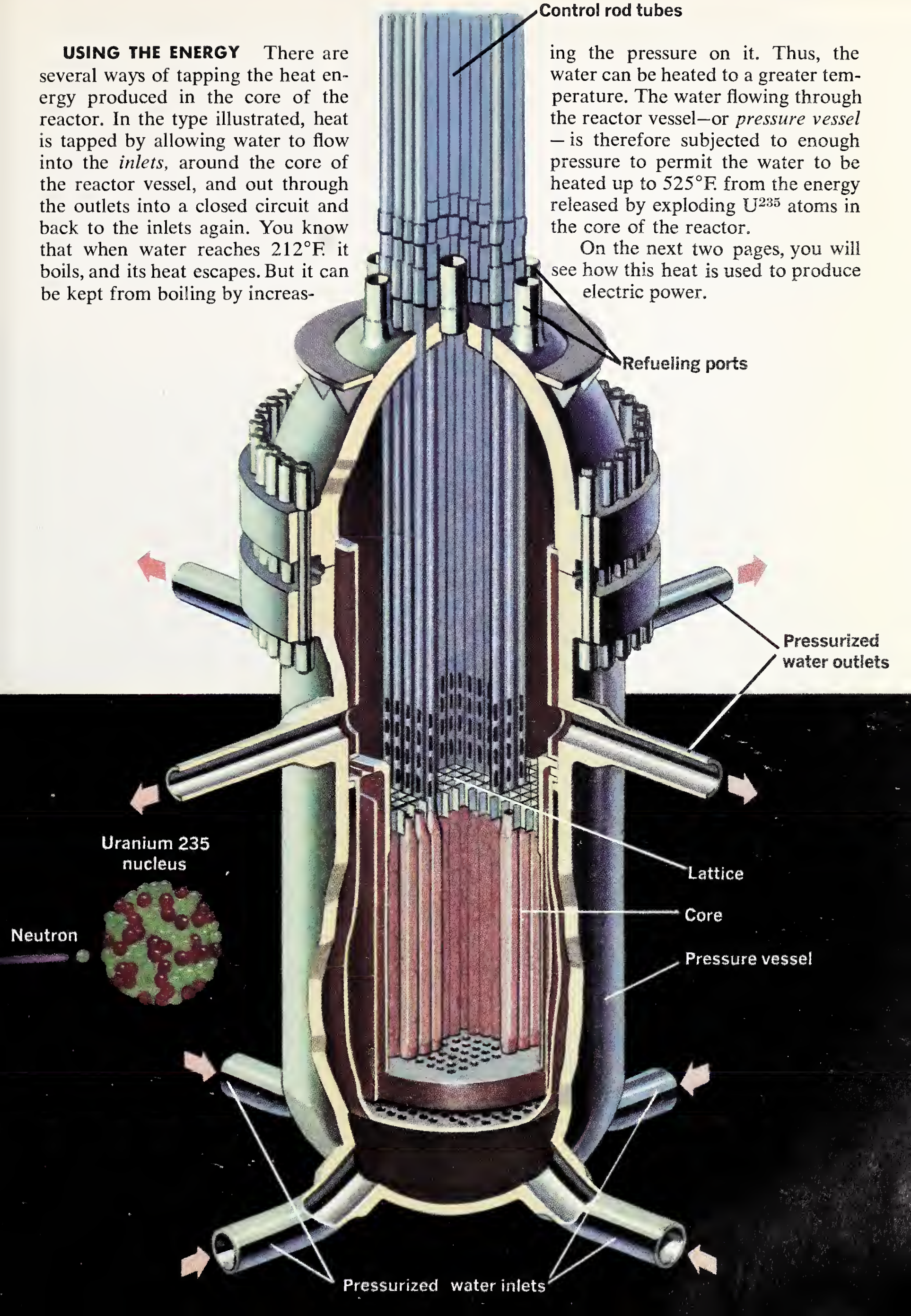
In a reactor, the speed of the reaction is controlled. The *core* of the reactor, consisting of fuel rods, is set in a *lattice* frame that absorbs some of the speeding neutrons. The fuel unit consists of *seed fuel rods* (containing *fuel plates* of U^{235}) and blanket rods (containing some U^{235} but mostly U^{238}). Cross-shaped *control rods,* made of material that, like the lattice, absorbs neutrons, can be lowered to decrease the speed of the chain reaction or raised to increase it. Thus the number of freely speeding neutrons is controlled, in turn controlling the rate at which nuclei split and the amount of heat energy produced.

The reactor shown on these pages is a *pressurized reactor,* the type used in the plant at Shippingport, Pa., which generates electric power for the Pittsburgh district.



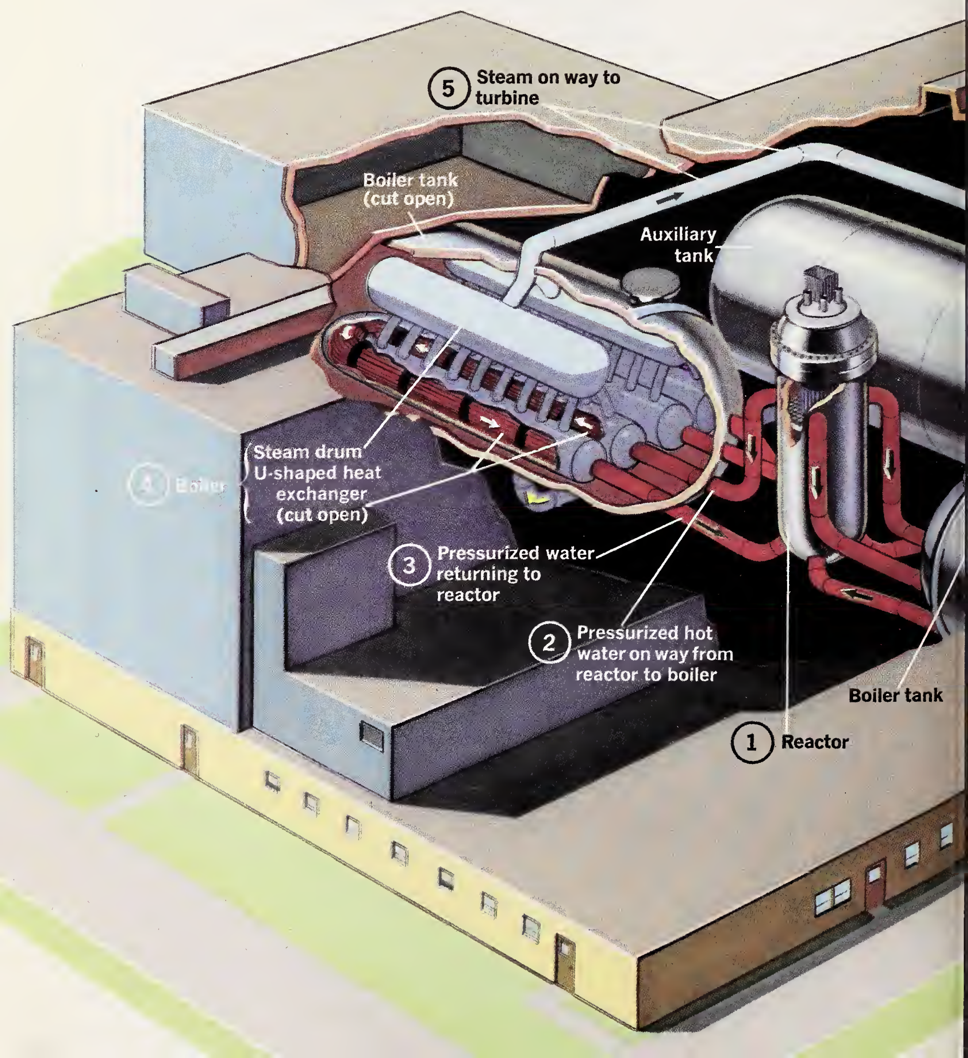
USING THE ENERGY There are several ways of tapping the heat energy produced in the core of the reactor. In the type illustrated, heat is tapped by allowing water to flow into the *inlets*, around the core of the reactor vessel, and out through the outlets into a closed circuit and back to the inlets again. You know that when water reaches 212°F. it boils, and its heat escapes. But it can be kept from boiling by increasing the pressure on it. Thus, the water can be heated to a greater temperature. The water flowing through the reactor vessel—or *pressure vessel* — is therefore subjected to enough pressure to permit the water to be heated up to 525°F. from the energy released by exploding U^{235} atoms in the core of the reactor.

On the next two pages, you will see how this heat is used to produce electric power.



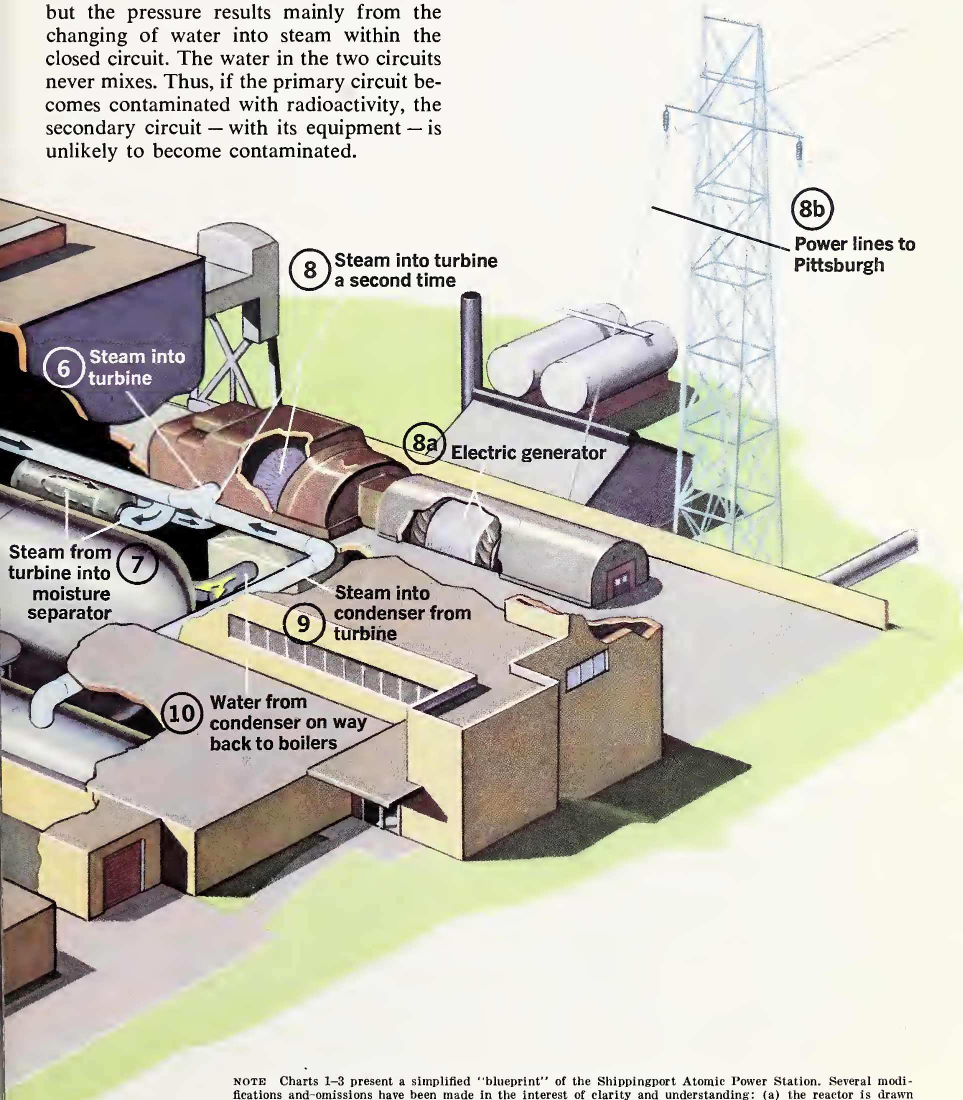
NUCLEAR ENERGY BECOMES ELECTRIC POWER At the Shippingport plant, energy released by atoms is changed into electricity. The water in the reactor is heated to about 525°F. but does not boil because it is kept under great pressure. The *auxiliary tank* contains equipment that keeps the pressure at the desired level and changes the water when necessary.

The closed circuit of water (**1-4,** shown in red) from reactor to *heat exchanger* (**4**) is called the *primary circuit*. It is heavily shielded by concrete and steel as protection against harm from dangerous radioactivity. The pipes from the boiler (**4**) to the turbine (**6**) and back to the boiler (shown in dark and light blue) are called the *secondary circuit*. Inside the heat exchanger, water from the secondary circuit (dark blue) flows around the heated coils of the primary circuit. The heat exchange between the water and the coils turns the water to steam (light blue) in the *steam drums* (**4**). The steam travels to the *turbine* (**6**) where it spins the high-pressure blades. This reduces the pressure of the steam and some of it condenses into water vapor. This moist vapor is removed in the *moisture separator* (**7**) and re-

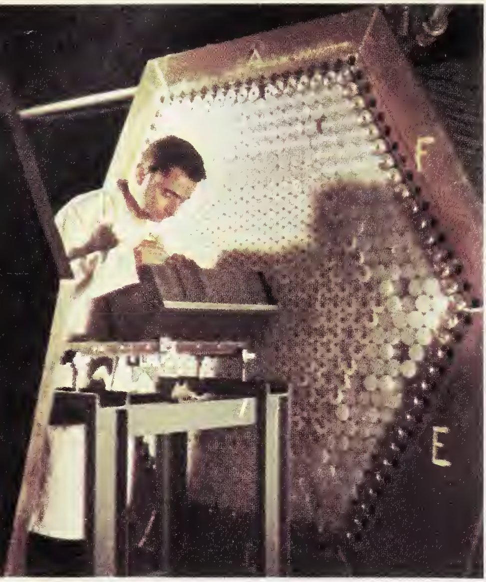


turned to the turbine to spin the low-pressure blades (**8**). Afterwards it is passed through a *condenser* (**9**) where a cooling jacket of water pumped in from the Ohio River turns the steam back to water to be returned to the boilers for the process to be repeated. The *secondary circuit,* too, is under pressure, but the pressure results mainly from the changing of water into steam within the closed circuit. The water in the two circuits never mixes. Thus, if the primary circuit becomes contaminated with radioactivity, the secondary circuit — with its equipment — is unlikely to become contaminated.

All this machinery is assembled for the purpose of generating (**8a**) electricity, up to a peak capacity of 80,000 kilowatts at any one time, for use by the Pittsburgh district.



NOTE Charts 1–3 present a simplified "blueprint" of the Shippingport Atomic Power Station. Several modifications and omissions have been made in the interest of clarity and understanding: (a) the reactor is drawn to a larger scale than the rest of the plant; (b) the long water canal, near the inner end of which the reactor is immersed, is not shown; (c) the connections between the primary circuit and the auxiliary tank are not shown; inside the tank is a pressurizer that maintains pressure in the primary circuit (*without* the need of a pump) and other equipment for changing the water in the primary circuit if necessary; (d) a concrete wall between the two heat exchangers within the cutaway boiler is not shown; (e) the bundle of pipes in the heat exchanger through which the pressurized water of the primary circuit flows has been greatly simplified; (f) the pumps (located under the turbine) that return the water from the condenser to the boilers are not shown; and (g) concrete walls sealing the atomic plant off from the building above ground level have been cut away.



ATOMIC RESEARCH By placing different elements into a nuclear reactor core scientists have obtained a number of new tools for experimental and practical use. The bombardment of neutrons released by nuclear fuel makes these elements radioactive and many of them find a use in medicine and research. *Left,* a physicist at the General Electric Knolls Atomic Power Laboratory in Schenectady is loading a nuclear assembly in a pioneer research reactor. *Below,* to avoid danger of an overdose of harmful radiation, this technician, wearing special gloves built into the protective shield in front of her, examines pellets of uranium oxide powder to be inserted into fuel elements made of zirconium rods.

RADIOISOTOPES IN MEDICINE The theratron is a powerful tool in cancer therapy. Radioactive cobalt, placed in the machine, emits gamma rays which can be directed to the site of some cancers, in order to destroy cancerous cells.

Top left: Jerry Cooke
Bottom left: Jerry Cooke
Bottom right: Memorial Center for Cancer and Allied Dieases

USES WITH PLANTS AND ANIMALS

Hundreds of radioactive isotopes are made in nuclear reactors. Scientists use these products in many ways to make new discoveries which may improve our manner of living. *Right,* the digestive system of a pig has many similarities to that of a man. By placing radioactive pellets in the pig's food, scientists try to discover where these substances are deposited in the body and what they do to it. What they learn increases our knowledge of what goes on inside a living body. Such information may have many uses. *Below,* plants are food factories for all of life on earth. By injecting radioisotopes into a food solution for plants, scientists are able to trace the kinds of elements plants take in through their roots and to calculate the amount of radioactive materials the plants store. At the Radiation Garden of the Brookhaven Atomic Laboratories on Long Island, many experiments are performed on plants. Some of these result in mutations—changes in the plants' characteristics which are inherited. The results are useful in giving us new information about living things.

Top: Jerry Cooke
Bottom: Brookhaven National Laboratory

MOBILE POWER By early 1959, the United States had launched five atomic submarines powered by uranium fuel, of which this, the *Triton,* is the fourth. Each submarine obtains its power from the heat generated in a nuclear reactor, well shielded amid ship. Heat exchangers convert water to steam, which drives the turbines that propel the ship. Each submarine can travel long distances under water without refueling.

FOOD PRESERVATION Here potatoes are irradiated in a distilled water column projecting down to the fuel element and shielded by 17 feet of water. These potatoes do not sprout, keep longer, and yet have absorbed no dangerous radioactivity.

In less than 20 years, many uses of atomic energy have been found. You are on the threshold of the Atomic Age. Perhaps you will discover new and important applications for atomic energy.

Photographs by Jerry Cooke

the sides of the heated test tube. Compare what you see there with the mercury in the bulb of a thermometer. What do you conclude as to elements that make up mercuric oxide?

3. *A model of hydrogen.* Make a model of an atom of hydrogen by using a soft rubber ball for a nucleus. Mold a small ball of plastic clay on the end of a wire and insert the other end of the wire into the rubber ball. The small ball of plastic clay represents one electron. Now hang up your model as a display in class. (Perhaps you can "make" other atoms.)

Put on Your Thinking Cap

1. The formula for hydrogen sulfide is H_2S. What does this mean?

2. How did the discovery of radium help scientists understand the atom?

Adding to Your Library

1. *Exploring the Atom* by Marie Neurath, Lothrop, 1956. Inside atoms are the smallest things we know and yet from them comes the mightiest force on earth. Read what the author has to say about diamonds, fire, X rays, and television.

2. *All About the Atoms* by Ira M. Freeman, Random, 1955.

3. *Atoms and People* by Ralph E. Lapp, Harper, 1956. This author has explained the atom to hundreds of groups of people who know nothing about science. He makes atomic science very interesting.

4. *Atomic Experiments for Boys* by Raymond F. Yates, Harper, 1952. If you want to make a cloud chamber or read a fascinating account about putting atoms together, this book will please you.

A Bit of Research

One of the most important tools of scientists who study the atom is a cloud chamber. From the books recommended in "Adding to Your Library" and from others you may find in your school library, prepare a report on how the cloud chamber has helped scientists unlock the secrets of the atom. The next step is to build a cloud chamber yourself. Directions for building a simple cloud chamber that will show the paths of atomic "bullets" may be had by writing to Editorial Office, Adventures Ahead, Dept. 2–111, General Electric Co., Schenectady, N.Y.

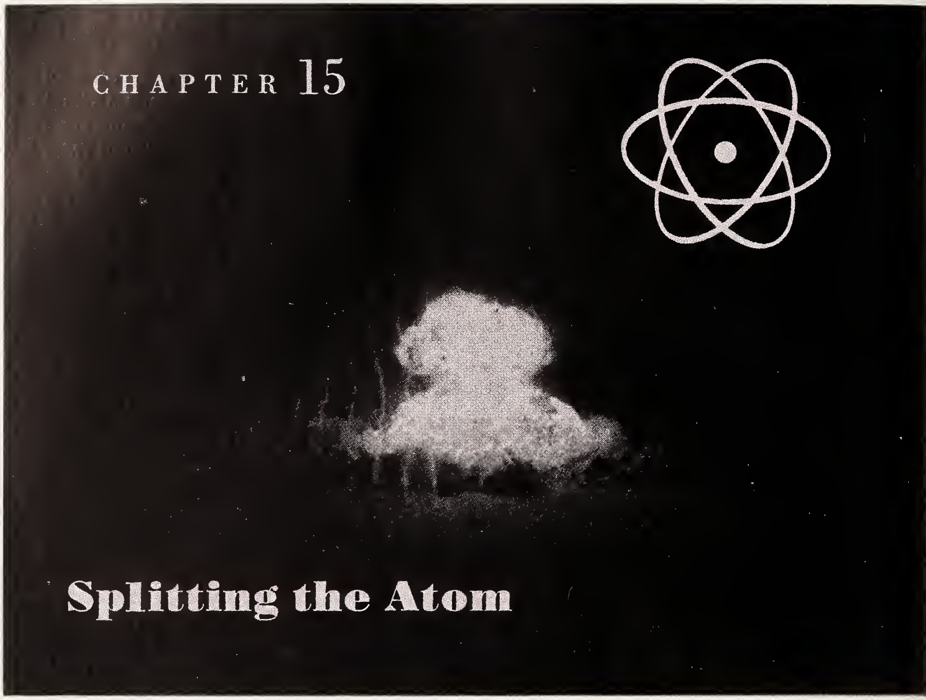
Careers for You

From the reading of this chapter and from your reference books you now have a good idea of the work of some of the scientists who have made important discoveries about matter and the atoms of which it is made. Every one of these important discoveries depended upon the work and help of hundreds, yes, sometimes thousands, of other men and women scientists who made discoveries of their own.

In large and small laboratories of industries and of local, state, and national governments there is a constant demand for science specialists such as *chemists* and *physicists*, and for *laboratory helpers* and *technicians*. Would *you* like to make an important discovery in science? or contribute to one? The opportunity awaits you if you go on in science.

CHAPTER 15

Splitting the Atom



An atom bomb goes off, and the terrible mushroom cloud rises. Atoms have split. But splitting atoms are being used for peace, too. An atomic engine has been built. And so has a heating plant using atomic energy.

On March 17, 1953, the morning sky over Las Vegas, Nevada, lighted up with a brightness one hundred times greater than the strongest sunlight. However, there was no excitement. Nor was there any panic when minutes later the air blast of an atomic bomb explosion struck the city. By this time people in Las Vegas knew all about atomic explosions. This was not the first to be set off eighty miles away.

What made this atomic test unusual was that two houses had been built for the test. One was two-thirds of a mile, and the other a mile and a half, away from the explosion. The scientists wanted to find out how houses as far away as that would stand up against the air blast.

Even though 3,500 feet away from the explosion, House No. 1 was completely destroyed. House No. 2, 7,500 feet away, stood, although damaged. Does this give you some idea of the giant power of the atom bomb?

This chapter is the story of scientists at work. It is the story of how they split atoms to make an atomic bomb and fused atoms to make a hydrogen bomb. It is also the story

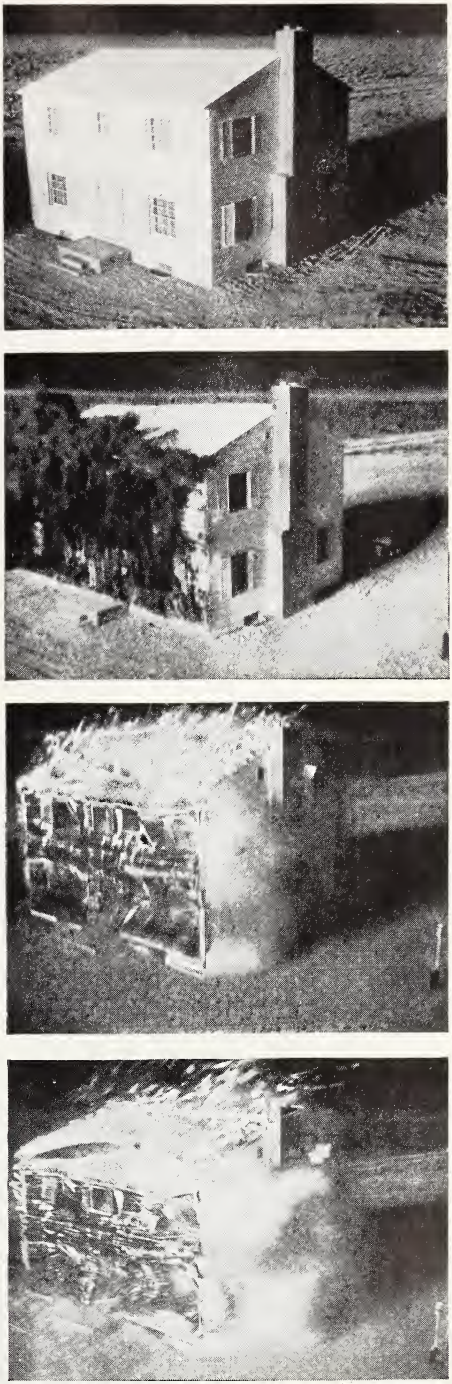
of what the future may bring if the great energy of the atom is used for peace instead of war. It is also the story of the element uranium and how scientists learned to use it.

THE SECRET OF URANIUM

Uranium is one of the most important elements found in the earth. It is so eagerly sought that just a whisper about the discovery of a new uranium deposit sends men rushing to get some of the land at the scene of the find.

However, uranium is never found lying around loose like gold. It is found combined with other elements. A dark, earthy mixture called pitchblende is very rich in uranium (Fig. 153). Pitchblende has been found in a very few places in the earth's crust, such as the Belgian Congo in central Africa, Canada, and Czechoslovakia. Only poor deposits are found in the United States, and these are in a region called the Colorado Plateau. However, much of our supply of uranium comes from this plateau.

No matter where uranium is found, it always has in it two kinds of uranium. One kind, uranium 238, is 99.3% of the total, and uranium 235 makes up the other 0.7%. That



USAEC

141 These pictures, taken in less than 4 seconds by a special camera, show the effect of an atomic bomb explosion on a house 3,500 feet (⅔ of a mile) from the center of the blast. *Top*, the undamaged house before the explosion. *Second picture*, the tremendous heat sets fire to the front of the house facing the explosion. *Last two pictures*, the fire is put out by the great blast of air, which blows the house apart.

is to say, in every 140 pounds of uranium there is 1 pound of the lighter uranium 235.

Scientists have found that uranium, like radium, is radioactive; that is, it gives off rays and particles as radium does. They also have found that it is the lighter uranium 235 which causes most of this radioactivity, although the heavier uranium 238 is also radioactive. It was about 1940 that uranium came to be considered a highly valuable element. Then scientists all over the world began to study its properties, using an instrument called the *cyclotron* (SYKE-luh-tron).

The Cyclotron

To find a way to break up the atom called for the best efforts of man's brain and hands. In Fig. 142 you see a diagram of a cyclotron, one of the so-called atom smashers, which weighs hundreds of tons.

One of the most important parts of the cyclotron is a hollow, divided copper disk. In a large cyclotron this disk is over 5 feet from edge to edge. It is about 2 inches thick but divided into halves, with a 2-inch gap between the halves (Fig. 142).

Because the hollow half-disks are shaped like two D's, they are called dees. The dees are placed in an airtight box surrounded by a powerful electromagnet.[1] The dees as well as the electromagnet are attached to a source of electricity.

Here is how the cyclotron works. Suppose a rabbit were placed in the exact center of a spiral track and were to run in a tiny fraction of a second once around the first small spiral. Then suppose some force made him run around the next longer spiral and the next in the same time. Since the spirals increase in length, pretty soon he is whizzing along at a terrific speed. This is exactly what happens in the cyclotron. Instead of a rabbit, atomic particles are shot into the center of the circle made up by the two dees. Let us follow the path of one of them, say a proton (Fig. 142).

First, the proton is "pulled" by electricity from one dee to the other dee at the rate of thousands of times a second. Each passage between the dees takes place at great speed.

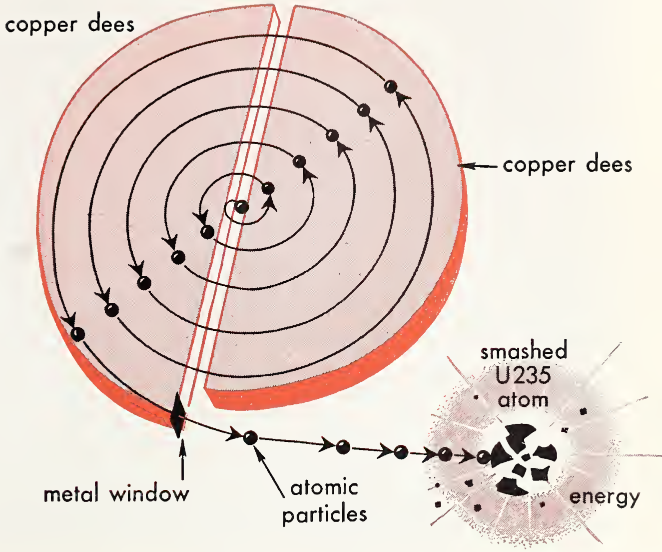
If the dees were not inside a powerful electromagnet, the proton would spend its time rushing back and forth between the two dees. But the strong pull of the electromagnet attracts the proton into a circular path that makes a spiral. What really happens, then, is that the proton keeps circling outward. As it circles, it goes faster and faster in each longer spiral until it is spinning near the wall of the hollow dees. At this point its speed may be over 100,000 miles per second. Now the proton shoots out of a metal window placed on the edge of one of the dees (Fig. 144).

In a thousandth part of a second, millions of these protons pass through the metal window. If they are allowed to escape into air instead of hitting an atomic target, they leave a blue trail several feet in length behind them. This beam is deadly. If a person exposed himself to it for a few seconds, he would die.

Changing Atoms

The particles leaving the metal window of the cyclotron may be thought of as atomic bullets. Strange

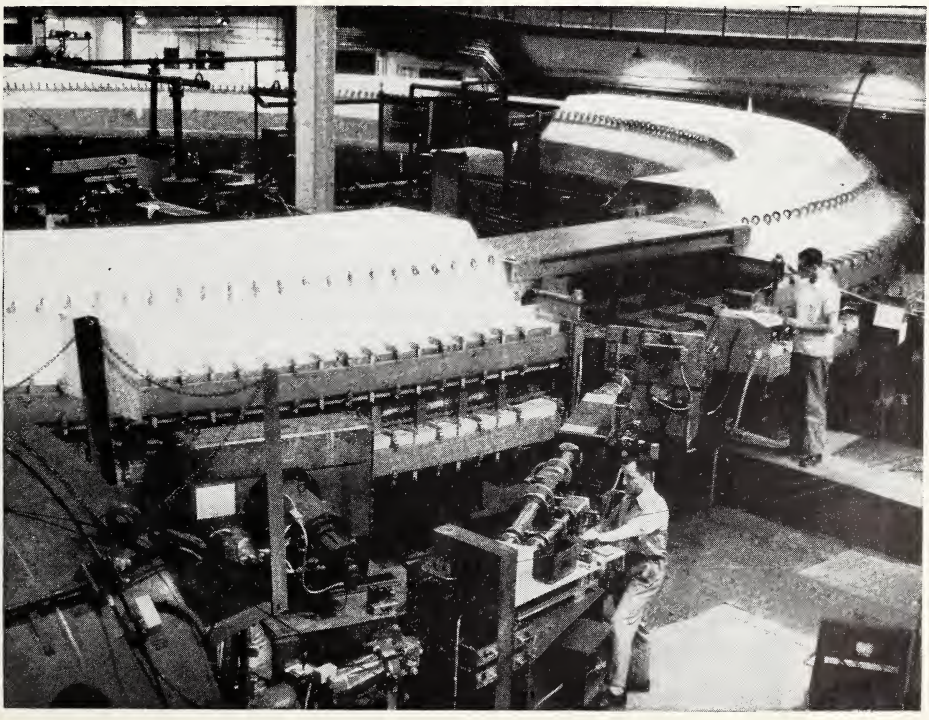
[1] An electromagnet is a magnet made by sending electricity through coils of wire wound around a bar of iron.



142 Atomic particles from a cyclotron split atoms of uranium 235, releasing energy.

143 This cosmotron speeds up atomic particles even faster than a cyclotron does. The atomic particles are sent into the machine where the two men are standing.

BROOKHAVEN NATIONAL LABORATORY



things happen when the nucleus of an atom is hit by these bullets. Radioactive phosphorus is made by bombarding sulfur in the atomic energy plants at Oak Ridge, Tenn. Even gold has been made from other elements by bombarding their nuclei.

Scientists are still working to build more powerful machines than the cyclotron. With these new high-speed machines they expect to learn more of the nature of the atom, more about treatment of cancer, more about how the elements and compounds of our world are put together.

WHAT IS ATOMIC FISSION?

Two scientists, Dr. O. R. Frisch and Dr. Lise Meitner (LEE-suh·MITE-ner), were among the first to bombard uranium with neutrons. They discovered that an atom of uranium behaves unlike any other atom. Instead of just changing its weight slightly, it splits into pieces. These pieces together weigh a little less than the original atom of uranium. Since weight is lost, it is clear that a small bit of uranium must have been changed into energy. It was shown later that if all the atoms in a pound of uranium 235 were made to split, or to undergo *fission*, this pound would give as much energy as could 5 million pounds of coal when burned or 9,000 tons of TNT when exploded.

The two scientists sent their findings to Dr. Niels Bohr, the great Danish scientist, who was Dr. Frisch's father-in-law. Dr. Bohr at once made plans to come to the United States. He reached New York on January 16, 1939, and there he set about getting ready for further work.

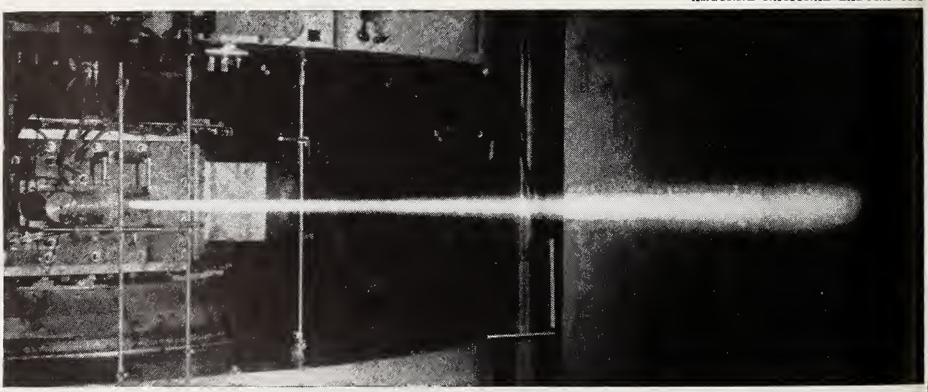
The Manhattan District

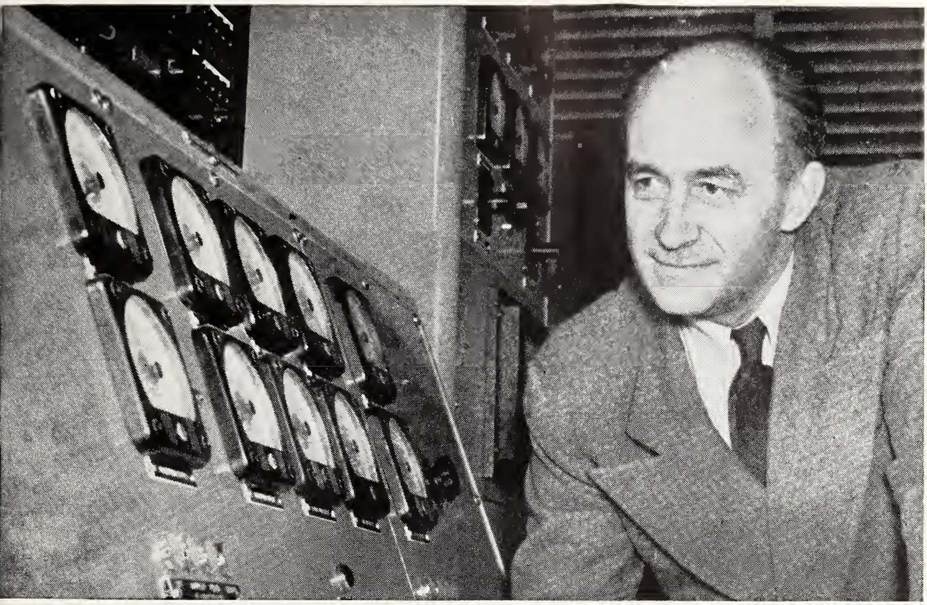
Together with Dr. Enrico Fermi (Fig. 145), an Italian scientist working at Columbia University, Dr. Harold Urey, and many other scientists, Dr. Bohr went on to find out more about splitting uranium atoms.

Fermi had found that the nucleus

144 Atomic particles are being shot out of the metal window in a dee of a cyclotron. What causes the beam of light?

ARGONNE NATIONAL LABORATORY




WIDE WORLD

145 Dr. Enrico Fermi, who died in 1954, is shown operating the controls of a new 100 million electron-volt betatron (BET-uh-tron) at the University of Chicago. The betatron and the cosmotron (Fig. 143) will help scientists find out what holds the nucleus of an atom together.

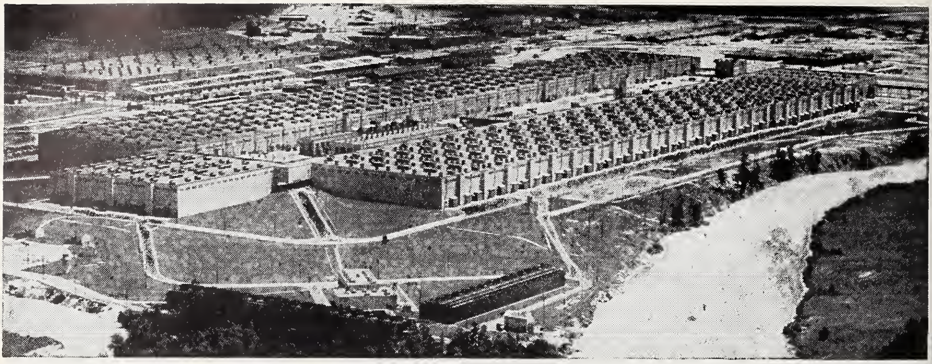
of an atom can easily capture neutrons shot at it if the neutrons are first slowed up. Fermi slowed up the speeding neutrons by passing them through carbon. Then it was easier for them to hit the real target, the nucleus of an atom.

This is what these scientists found when they worked with "slow" neutrons: when an atom of uranium 235 is hit by slowed-up neutrons, it breaks into several parts. *But it also shoots out more neutrons.* These neutrons, in their turn, hit other atoms of uranium 235 and break them up — and more neutrons are produced. As each atom breaks up, a part of the atom turns into energy. This energy is very, very great, beyond that of any known fuel. At once there came into the minds of the scientists the idea of breaking up atoms, one after the other, in a *chain reaction.* This would result in a huge amount of energy.

If an atom in a sizable amount, or mass, of uranium 235 were once split, atoms next to it could be split by the neutrons coming from the first atom. The result might be a tremendous explosion in a millionth part of a second.

The Birth of the Manhattan District

To get atoms to split up in a chain reaction, a sizable mass of uranium 235 was needed. This could be collected by separating it from ordinary uranium. This would be a very hard task because both kinds of uranium (uranium 235 and uranium 238) are chemically the same; the only difference is in weight. Could any means



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146 A plant at Oak Ridge, Tenn. Here uranium 235 is separated from uranium 238.

be found to separate uranium 235 from uranium 238 on a large scale? There was only one agency big enough to undertake the job — the United States government. The government was then interested in uranium 235 because it hoped that a bomb made of it would bring a quick end to World War II.

By the spring of 1943, the government had brought together the best scientific brains of the nation to tackle the job of splitting the atom. Dr. Vannevar Bush headed a committee of scientific advisers, and the job of making an atom bomb was begun under Major General Leslie Groves and Dr. Robert Oppenheimer. At Oak Ridge, Tenn., the great plants for separating uranium 235 from natural uranium were built (Fig. 146). At Hanford, Wash., other great plants were built. Over 2 billion dollars were spent on this project, even though no one was really sure it would succeed. The whole project was called the Manhattan District, and it was kept secret in the hope that only a few of the top people working on it would have a complete picture of what was going on.

The Separation of Uranium 235

As you know, uranium 235 is a little lighter than uranium 238. It can be separated from uranium 238 by heating. A uranium compound is heated at very high temperature until it turns into a gas. This gas is passed through a fine screen. The molecules of uranium 235, being lighter than those of uranium 238, pass through the screen more rapidly (Fig. 147). They are immediately drawn away by pumps. Thousands upon thousands of special screens are needed, as well as giant pumps for drawing the gas molecules through the screens. Finally, the lighter uranium 235 comes from the last screen in pure vapor and is cooled. Then it becomes the solid metal, uranium 235. How hard it is to get this metal will be clear to you if you recall that in 140 parts of uranium there is only one part of uranium 235.

Now that pure uranium 235 could be made, the scientists at Oak Ridge had the kind of uranium that could start a terrific chain reaction. In other words, they now had the material to

make an atomic bomb. Some of this uranium 235 was sent to the University of Chicago, where the first chain reaction in history was to be set off.

THE FIRST CHAIN REACTION

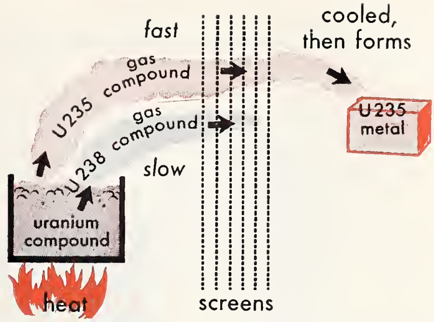
In the afternoon of December 2, 1942, scientific history was made in the football stadium of the University of Chicago. It was not made upon the football field but in a large room beneath the west stands of the stadium. An outsider looking into that room would have seen a strange sight.

In the center of the room, covered on all but one side by balloon cloth, was a square pile of black bricks and wooden timbers. On a balcony at one end of the room stood a group of scientists, among them Dr. Enrico Fermi and Dr. Arthur Compton. Some of the scientists were looking anxiously at the dials of instruments. The instruments gave off a loud clicking sound. Other scientists stood tensely by, their hands on switches and control rods.

Dr. Fermi spoke: "Move the central control rod out six inches more." One of the scientists pulled it out. The clicking sound rose to a roar, then leveled off. Fermi called, "Pull the rod out another foot!" At once the roar increased and kept increasing. *It did not level off*. Fermi made lightning-like calculations. After three minutes his whole face broke into a smile.

"We have a chain reaction," he announced. "Push in the control rod." The clicking slowed down and stopped.

That very afternoon Arthur Compton called James B. Conant of Harvard University by long-distance telephone.



147 Pumps draw the lighter uranium 235 (gas) through porous screens faster than they do the heavier uranium 238.

"The Italian navigator has landed in the New World," said Compton.

"How were the natives?" asked Conant.

"Very friendly," answered Compton.

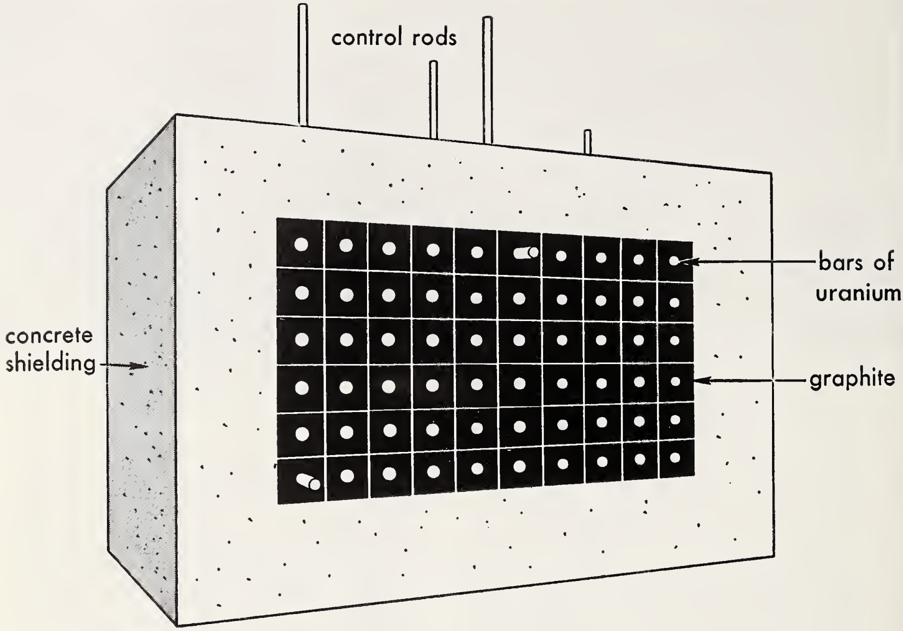
This code meant that for the first time in history man had brought about a chain reaction of splitting atoms and had stopped that action. Man had set free the energy of the atom and had controlled that energy. To do this, he had built the world's first *atomic pile*.

AN ATOMIC PILE

No doubt you have now guessed what was under the balloon cloth.

It was an atomic pile.

Dr. Fermi, along with other scientists, had built it. They had placed bars containing uranium 238 and uranium 235 in carbon blocks and built them up into a certain size that they called a *pile*. Neutrons already in the atmosphere cause some U 235 atoms to split and shoot out more



148 Notice the cadmium control rods on top of this operating atomic pile. They control the chain reaction caused by the splitting of uranium 235 atoms. Some of the bars, or rods, of uranium are uranium 238, as well as uranium 235. Why is the concrete shielding used? *Project:* Build a model of an atomic pile. You may get photographs from the Atomic Energy Commission.

neutrons. In the pile, these fast-flowing neutrons were slowed by carbon blocks. Then they could split additional U 235 atoms, thus starting a chain reaction.

Great amounts of heat came from the splitting of the atoms in the chain reaction. But how could this chain reaction be made to continue by itself? In other words, how could the heat be controlled?

Dr. Fermi and his fellow scientists found a way to do this.

They knew that the flow of neutrons caused chain reactions in uranium. They thought that, if they could find a substance that could sop up, or absorb, neutrons, they could control atomic energy. They found the substance in the element *cadmium*, a grayish-white metal. They made this metal into rods which were placed in the pile.

When cadmium rods are pulled out of an operating pile, atomic fission begins. The chain reaction starts. When they are pushed in, atomic fission slows down and finally stops. When Fermi called, "Move the central control rod out six inches more," more neutrons started a faster chain reaction. When he said, "Push in the control rod," the chain reaction slowed down and stopped (Fig. 149).

Today, all this is done by machines operated by men far away from the dangerous pile. Because a uranium pile throws off rays deadly to human

life while it is in operation, it is placed in heavy walls of concrete (Fig. 148). The walls of concrete stop the rays.

Such atomic piles in operation give off heat beyond imagination. The atomic energy plant at Hanford was built beside the Columbia River because it takes the entire water flow of that great river, cold as it is, to carry away the heat made by the operating piles.

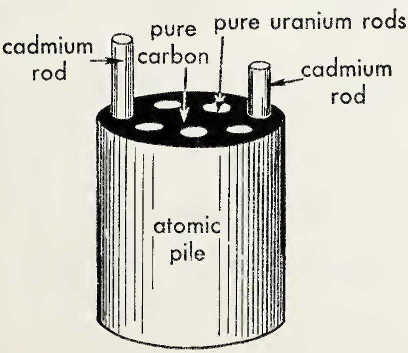
As you will learn later, it is this heat energy from operating atomic piles that may replace our present fuels, coal and oil.

The Discovery of Plutonium

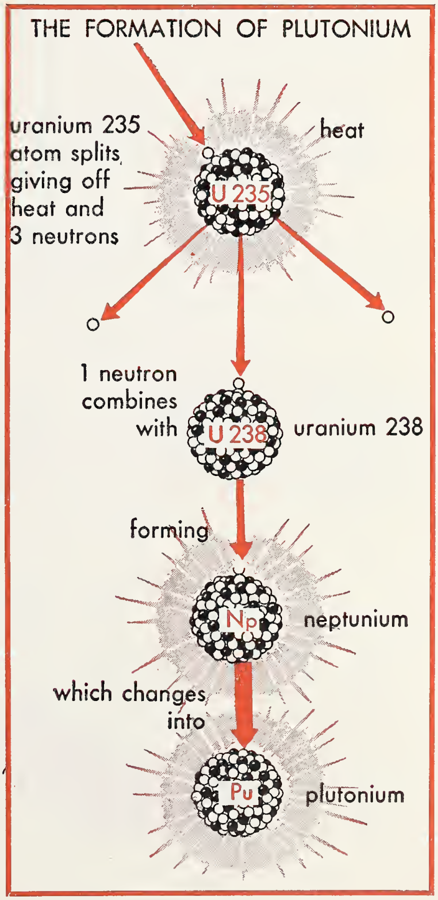
In his small atomic pile in Chicago, Dr. Fermi traced what happens when uranium 238 is bombarded by neutrons. He and the other scientists working with him discovered that, in the pile, some of the uranium 238 changes into an entirely new element. This new substance was given the name *neptunium*. It is highly radioactive, breaking up into many particles, protons, neutrons, and electrons.

Neptunium itself changes rapidly into another element. Scientists found that this new element also splits easily. They called this second new element *plutonium*. So, on the trail of splitting the atom, scientists discovered the new atoms, neptunium and plutonium.

149 The flow of neutrons in an atomic pile is slowed up by the carbon. The number of neutrons which are free at any one time is controlled by pushing in and out the cadmium rods. The cadmium rods absorb neutrons. Why are the cadmium rods movable?



150 The making of plutonium starts when a neutron from a splitting uranium 235 atom enters the nucleus of a uranium 238 atom to make neptunium. Neptunium changes rapidly into plutonium.



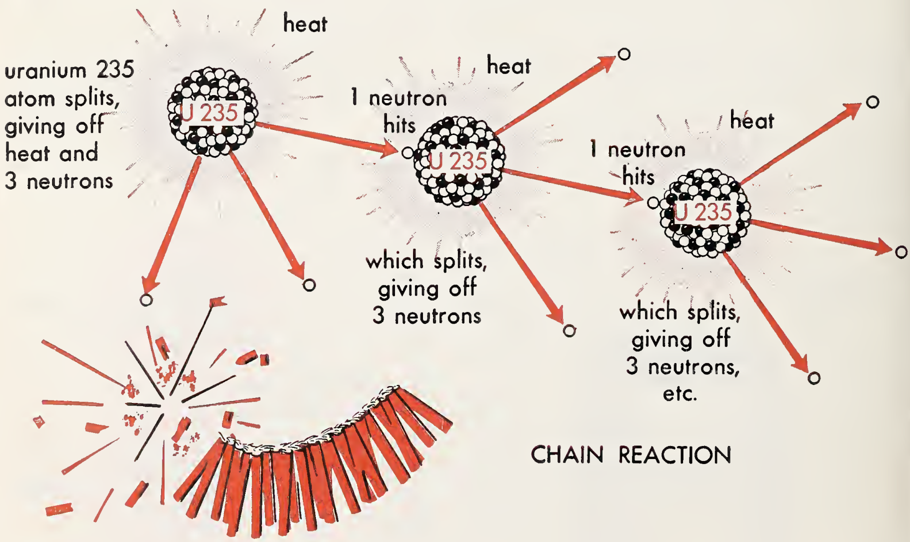
THE FIRST ATOMIC BOMB

The Manhattan District did not end with the making of the first atomic pile and the discovery of new atoms. Scientists now knew they could start a chain reaction in atoms of uranium and plutonium. In the laboratories at Los Alamos, N.M., plans were laid for putting together the first atomic bomb. From the huge plant at Oak Ridge, Tenn., came that very important material, uranium 235.

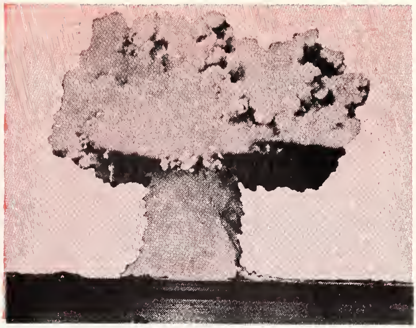
Scientists knew that, in the pure state, uranium 235, as well as plutonium, must be kept in amounts below a certain size, called the *critical mass*. The reason for this is that even small amounts of these metals throw off dangerous amounts of neutrons. Some of these neutrons escape, but others may start a chain reaction as they hit other uranium 235 or plutonium atoms (Fig. 151). When the amount of the plutonium or uranium 235 brought together is large enough, above the critical mass, an atomic explosion occurs.

Chain reactions in pure uranium 235 or plutonium can be stopped by storing these elements in small amounts (below the critical mass). They are kept separate from each other. The first atomic bomb to be tested was built to bring together two small amounts of uranium 235 at the proper second to make a mass beyond the critical size (Fig. 152). Since the explosion would happen almost at once, the bomb had to be built to force the separate amounts of uranium together at the right moment to cause the explosion.

151 One neutron given off by a uranium 235 atom strikes another uranium 235 atom. Suppose there were billions of uranium 235 atoms packed closely together. Can you see how a chain reaction or an atomic explosion might happen?



152 Trace what happens in an atomic explosion.



In the Heart of the Explosion

To get the explosion of the first atomic bomb, the critical mass of uranium 235 weighed a little over two pounds. You could hold this weight easily in the palm of your hand. Yet the explosion of this small amount of uranium 235 produced a temperature of almost 100,000,000° F. If a marble could be heated as hot as that and be placed on a desk in front of you, you and the entire contents of the room would at once be burned to a crisp! Fortunately, it can't be done. You can get a better idea of a temperature of 100,000,000° by comparing it with the heat at the sun's surface. At the surface of the sun, which gives us all our light and heat, it is 10,000° F. Can you now understand how even a half-mile from the center of the explosion of an atomic bomb, the heat alone is enough to kill all life?

Along with the terrific heat of the explosion come showers of neutrons which hit every object in their path over a large area. With these showers of neutrons are showers of powerful gamma rays (like X rays).[1] Also, the blast of air set in motion by the explosion is heavy enough to destroy buildings two miles from the center (Fig. 141).

Other Effects of the Explosion

Within a few thousandths of a second after the explosion, a "fireball" appears as the air is changed to a glowing mass by the great heat. In 1 second this fireball, about 900 feet wide, begins to rise like a huge gas balloon. In 10 seconds, the light of the fireball, one hundred times brighter than the sun, dies down. Then a huge cloud with sucked-up dirt and wreckage rises like a mushroom 40,000 feet into the sky (Fig. 152). Winds carry radioactive dust from this cloud over wide areas of the earth's surface.

More Powerful Explosions

Since the explosion of the first atomic bomb in 1945 there have been a great number of other atomic explosions. Up to August 1958, the United States has tested over one hundred atomic bombs. And in these tests were explosions of *hydrogen bombs*. The explosions of hydrogen bombs

[1] Gamma rays from an atomic explosion may injure unprotected people a mile from the blast.

are much more powerful than explosions of atomic bombs.

THE HYDROGEN BOMB

You have learned that the giant energy of an atomic explosion comes from *splitting* uranium or plutonium atoms. This is called *atomic fission* (p. 294). However, even greater energy can be made by fusing hydrogen atoms. When hydrogen atoms are fused (united) in the hydrogen bomb, they make helium. This process is called *atomic fusion.* Atomic fusion, like atomic fission, turns matter into energy.

The Secret of the Sun and Stars

The sun and stars are fusing hydrogen atoms together to make helium day in and day out, year after year. The sun's heat and light come from the energy of this fusion. The sun loses 4½ million tons of its matter every second in giving off heat and light. But the sun is so huge that it will still have 99.9% of its size left after another 15 billion years.

Man-Made Atomic Fusion

How could scientists duplicate on earth what happens in the sun and stars? They have done it by using the 100,000,000-degree heat of an atomic explosion to "trigger" or start the fusion of hydrogen into helium. In doing this, scientists have made a *hydrogen bomb.* Of course, the actual way in which the bomb is made is a military secret, but the materials used are well known.

You remember that hydrogen is our lightest element (see p. 283). Ordinary hydrogen, with atomic weight of 1, is the kind of hydrogen that keeps an ordinary toy balloon in the air. There are different kinds of hydrogen, just as there are different kinds of uranium. Double-weight hydrogen, which we shall call hydrogen 2, and triple-weight hydrogen, which we shall call hydrogen 3, are the kinds of hydrogen used to make a hydrogen bomb. In other words, hydrogen 2 weighs twice as much as ordinary hydrogen, and hydrogen 3 weighs three times the weight of ordinary hydrogen.

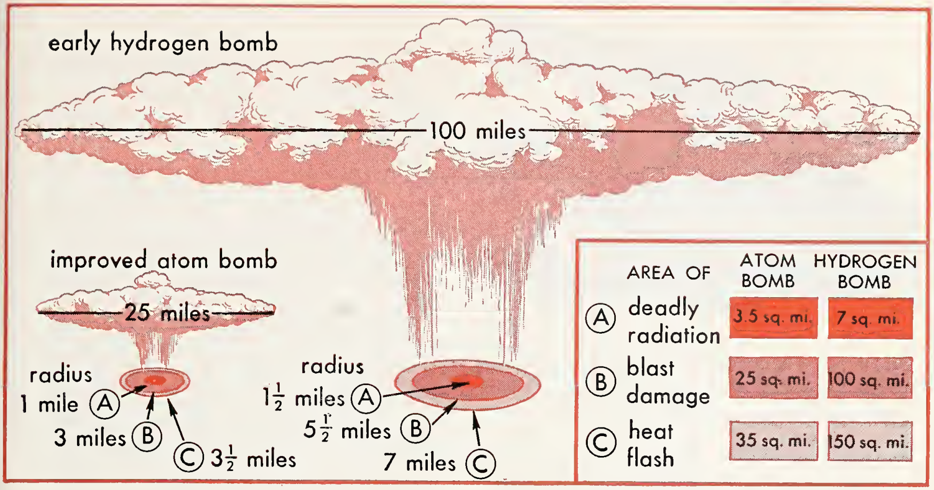
Hydrogen 2, or heavy hydrogen,[1] can be made by the ton without too much trouble from a kind of water known as *heavy water.* There is a tiny amount of this heavy water in every drop of ordinary water.

It is very expensive, however, to make even a pound of hydrogen 3. This extra-heavy hydrogen is very rare. Scientists who found it for the first time in ordinary water estimated that the whole of Lake Michigan would yield only one-tenth of an ounce of hydrogen 3. And so scientists found another way to make hydrogen 3, or tritium. They made it in atomic piles, in which, you may recall, substances may be bombarded with neutrons.[2]

In the hydrogen bomb there is a mixture of hydrogen 2 and hydrogen 3. This mixture is surrounded by a certain mass of uranium 238. The mixture of hydrogen 2 and hydrogen 3 is fused into helium by the 100,000,-

[1] Hydrogen 2 is also called *deuterium* (dyoo-TEER-ee-um). Hydrogen 3 is called *tritium* (TRIT-ee-um).

[2] To make hydrogen 3, the element lithium is bombarded with neutrons.



153 The explosive power of the first hydrogen atom blast set off in November 1952 was 250 times greater than that of the improved atom bomb. In March 1954, hydrogen bomb explosions 750 times more powerful than an atomic bomb explosion were set off.

000-degree heat of an exploding atomic bomb. The giant heat of this fusion causes even the uranium 238 to fission. When first produced, the result was the greatest explosion ever recorded.

The Explosion of the H-Bomb

Nothing man has done in the history of science has matched the awful power of the hydrogen bomb. Unlike the atomic bomb, the hydrogen bomb has almost no limit to its size or power.

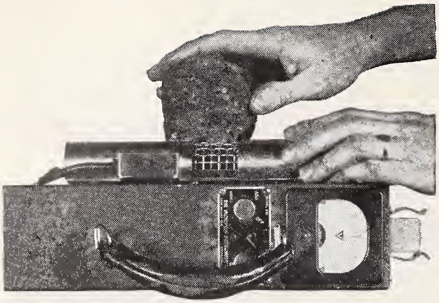
The first test explosion of a hydrogen bomb took place November 1, 1952, on an island in the Eniwetok Atoll in the Pacific Ocean. The island, 13 square miles in area, actually disappeared beneath the sea.

More powerful hydrogen bombs have since been exploded. A comparison has been made to show how much greater damage the first hydrogen bomb could cause over that which could be caused by the improved atomic bomb. And in the mushroom-shaped clouds pictured above there is radioactive dust (Fig. 153).

FALL-OUT

When radioactive dust from an atomic or hydrogen bomb explosion falls back to earth, scientists call the dust *fall-out.* Fall-out may be dangerous to life. Some fall-out from the first atomic bomb explosion is still settling on the earth, and continued test bomb explosions add more fall-out.

On March 1, 1954, a hydrogen test bomb was exploded on Bikini, an island in the South Pacific Ocean. The explosion of this bomb was 750 times more powerful than the explosion of the first atomic bomb (Fig. 153). Just 71 miles northeast of the island, the crew of a Japanese fishing



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154 Here is a Geiger counter showing the radioactivity of allanite, a radioactive ore (like pitchblende in appearance).

boat noticed an unusual happening. The sky lighted brighter than sunlight. Afterward a fine gray ash settled, getting into the hair, noses, and even the mouths of the crew. But it was just an annoyance, so they kept on fishing.

However, a few miles away the same dust was falling on ships of the United States fleet. On the decks of the ships men in protective clothing washed away the dust as fast as it fell. Scientists knew how dangerous this dust was and had provided means to get rid of it.

Because the Japanese fishermen did not know the danger of this fall-out of radioactive dust, they became very ill. Fortunately, all but one of the crew recovered.

On January 14, 1958, a petition to stop the testing of atomic and hydrogen bombs by international agreement was presented to the United Nations. It was signed by over 9,000 scientists who believed that radiation from world-wide fall-out would become a hazard. Many other scientists believed that this would not happen. They believed that the testing was necessary for the development of different kinds of atomic bombs, and most important, to make a "clean" atomic bomb. A clean atomic bomb is one that has little or no radioactive fall-out.

On July 19, 1957, a jet plane exploded an atomic bomb 15,000 feet above a group of men standing on the ground below. These men wore no helmets, no sunglasses, and no protective clothing.

At the instant of the explosion, the men looked up, saw the fireball, and felt the heat. Then they waited for the shock wave to arrive — about ten seconds. When the shock came there was actually just a loud noise. After the blast and heat waves had passed, the men checked their radiation instruments while the cloud formed by the explosion drifted away. Their instruments detected just a little radioactive fall-out. Scientists were on the trail of developing a clean bomb.

CONTROLLING FALL-OUT

The making of a clean atomic bomb is one help in controlling fall-out. Another way is to test atomic bomb explosions underground so that no radioactive particles get into the atmosphere.

On September 19, 1957, an atomic bomb was exploded underground in Nevada. It pulverized 700,000 tons of rock. It was part of a series of underground bomb tests to prove whether atomic bomb explosions might be useful in mining operations and in the deepening of harbors.

Scientists are continually searching for further ways of controlling fall-out. But to detect fall-out or any substance that is radioactive, they use sensitive instruments.

Detecting Fall-Out

One of the instruments used to detect fall-out is a Geiger counter. It is also used to locate uranium ore. When any radioactive particles pass through the tube of the counter, a click is heard and the pointer moves over a scale (Fig. 154).

Not every click in the Geiger counter means radioactive fall-out or uranium ore. The clicks of the Geiger counter are heard before it is brought near any radioactive materials. These are from rays that bombard the earth from outer space. They are called *cosmic rays*, and they cause the counter to click in a slow and uneven way. The rays may be caused by atomic explosions in the sun and stars.

Sometimes, however, the Geiger counter begins to click faster than the background clicks caused by cosmic rays. Suppose there is no radioactive rock nearby. What may have caused these clicks? They were probably caused by the fall-out from atomic explosions, even though the explosions may have been several thousand miles away. By using the Geiger counter and other instruments, scientists may learn that an atomic explosion has taken place no matter where or in what country. It is the radioactivity of the fall-out that tells them.

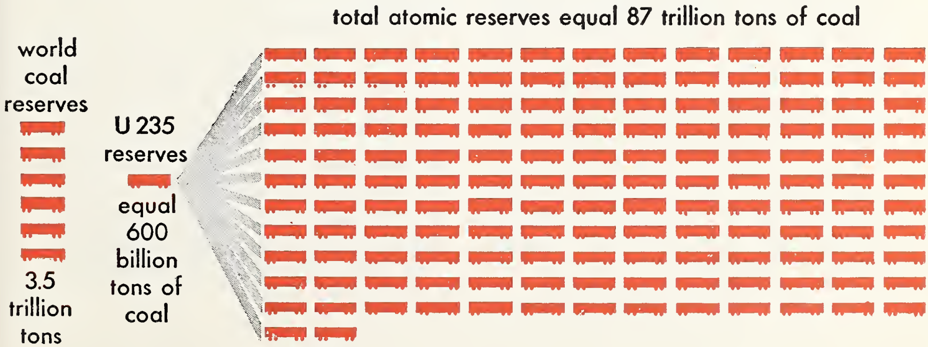
If there is no possibility of recording fall-out, a prospector knows that uranium rock is probably present when his Geiger counter begins to click faster. The number of clicks *in a certain time, such as a second or a minute*, tells him something of how rich in uranium the rock is.

Sensitive instruments, such as the Geiger counter, are very necessary in industry, medicine, and agriculture, where the peaceful uses of the giant energy of the atom are put to work. It is these peaceful uses of the atom that are most important to your lives and to the lives of future generations. Right now, let us look into some peacetime uses of atomic energy.

Energy

How can we use the giant energy of the atom for peaceful purposes? Atomic explosions cannot be con-

155 If uranium 235 were our only source of atomic energy, we should have enough of it to equal the energy stored in 600 billion tons of coal. However, other materials which may be used for atomic energy make our total sources of atomic energy equal to the energy stored up in 87 trillion tons of coal.



GENERAL DYNAMICS CORP.

156 The world's first atomic-powered submarine, the *Nautilus*, is launched. Its atomic engine may be the forerunner of atomic engines for ocean liners.

trolled, once they start. If atomic energy is to be used for peacetime purposes, it must be controlled without explosion. This control is possible in atomic piles (pp. 298–299; also, study Atomic Energy Charts 2 and 3 at p. 288).

Scientists have been able to build different kinds of atomic piles which use different materials, but each one uses the very rare and expensive uranium 235. These piles are called *nuclear reactors*. In nuclear reactors atoms are split to produce energy.[1] The chain reactions in these reactors result in so much heat that the reactors are used to generate electricity for power stations and for engines in submarines and ships (see Atomic Energy Charts following p. 288).

[1] You will hear the terms "atomic reactor" and "nuclear reactor" or "atomic submarine" and "nuclear-powered submarine." In usage, "atomic" and "nuclear" are synonymous and are so used in this text.

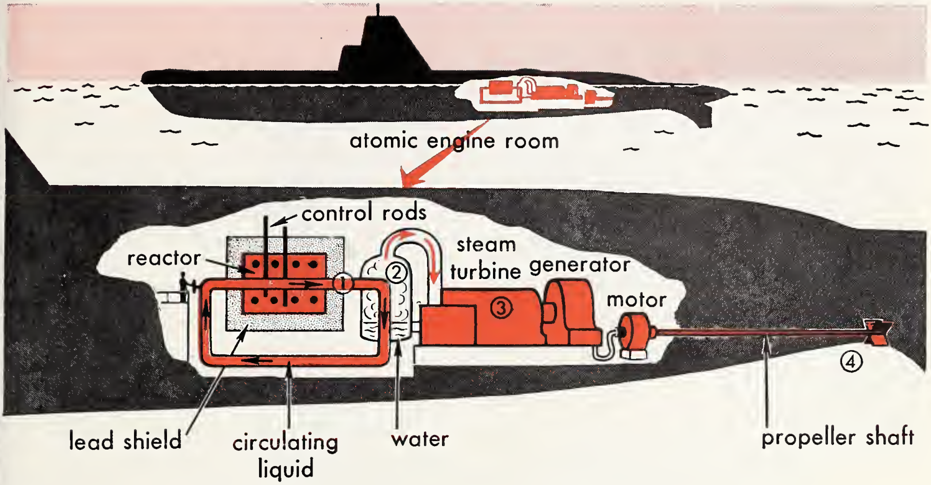
Power Plants

Except for using splitting atoms for fuel, an atomic power plant is much like an ordinary power plant that uses oil or coal for fuel. Fig. 157 shows a diagram of a power plant for an *atomic-powered submarine.* Notice that the heat of the nuclear reactor is carried off by a special liquid.[1] This liquid becomes very hot. Then this very hot liquid passes into the "heat exchanger," where its heat turns water into steam (Fig. 157). The energy in the steam is turned into electricity. The electricity drives the submarine through the water by turning the propellers.

The first atomic, or nuclear, engine was installed in the submarine *Nautilus*, launched on January 22, 1954 (Fig. 156). Two years later the second submarine, the *Sea Wolf*, was launched. The third atomic submarine, the *Skate*, took to the sea in May 1957, and was soon followed by the *Triton* (Atomic Energy Chart 5). In April 1959, the *Skipjack* was launched, embodying all the advances in nuclear engineering up to that point. By 1962, the U.S. Navy will have launched over twenty-five atomic submarines.

An atomic submarine (Fig. 157) seldom requires refueling with uranium. An atomic submarine can travel under water for very long distances because the uranium, as you know, does not require oxygen to re-

[1] The "liquid" is a metal which has become liquid because of great heat. This liquid metal is, of course, much hotter than boiling water.



157 Follow the sequence: (1) A special liquid circulating through the reactor is heated to a high temperature. (2) The heated liquid turns water in this tank to steam (3), which runs the turbine and generator (4), which generates electricity to run the motor which propels the submarine.

About two pounds of uranium 235 (the size of a golf ball) in the reactor of the submarine *Nautilus* would give as much energy as 460,000 pounds of fuel oil or 3,000 tons of coal. Besides saving fuel space, what are other advantages of atomic-powered submarines?

lease its energy. On July 23, 1958, the *Nautilus* started from Hawaii, passed under the ice at the North Pole August 3, 1958, and on August 5 came to the surface of the North Atlantic Ocean. By September 1958, the *Nautilus* had traveled 130,000 miles with only one refueling of uranium.

The submarine *Skate* accomplished the same feat from the opposite direction just eight days after the *Nautilus* found the North Pole. In August 1958, the *Sea Wolf* traveled for sixty days under water in the Atlantic Ocean without resurfacing. Atomic power in submarines is a success.

Atomic engines will soon be used in surface ships. The *Long Beach*, the first atomic-powered cruiser in the U.S. Navy, was scheduled to be launched in 1959. The *Savannah*, an atomic-powered cargo ship, was scheduled for sea in 1960. The *Enterprise*, an 85,000-ton aircraft carrier with eight nuclear reactors, was scheduled for launching in 1961.

On land, the great power of the atom is being used to generate electricity. On December 23, 1957, the first land-based atomic reactor began operating an electric power station at Shippingport, Pa. (Atomic Energy Chart 3). It produces enough electricity for 120,000 people. Twenty other atomic power stations are being built. When the cost of generating electricity by using atomic energy becomes less than by using coal or oil, we will have limitless power.

And right now we are on the threshold of using the waters of the ocean for atomic fuel.[1]

Atomic engines for airplanes are now being tested at Arco, Idaho. Just as an atomic-powered ship can cruise for months without refueling, so can an atomic-powered airplane keep aloft that long.

For those who expect atomic-powered automobiles, the answer is "No," at least in the near future. One of the great problems in building any atomic-powered engine is to protect people from the deadly rays that come from the reactor. In the atomic-powered engine in Fig. 157, the nuclear reactor — the place where atoms are being split — has a heavy lead shield around it to stop these rays. No way has yet been found to make this shielding light enough and yet safe enough for an atomic-powered automobile engine.

However, atomic energy has another great use today. From it we are getting *radioactive materials* for medical, agricultural, and industrial use.

RADIOACTIVE MATERIALS IN EVERYDAY LIVING

Radioactive materials are made in atomic piles. When bombarded by neutrons set free in the piles, atoms of most elements become radioactive. The neutrons cause a change in the atoms they bombard. For example, atoms of nitrogen with atomic weight of 14 are changed by the neutrons which hit them into radioactive carbon atoms with atomic weight of 14. Radioactive carbon is different from ordinary carbon in one important way. It is unstable; it changes. It is so unstable that the carbon 14 changes quickly back into nitrogen. As it does so it gives off strong radiation.[1] This radiation, as you remember, is measured by Geiger counters.

Almost any element can be made *radioactive;* that is, it can be made to give off particles and rays. The Atomic Energy Commission is now making many many different radioactive substances in the laboratories at Oak Ridge, Tenn. Some of these substances were made in small amounts and at high cost in cyclotrons before World War II. Now they are made in greater amounts at low cost and then are sent out for all kinds of research. For example, in just a few weeks an Oak Ridge pile made a certain amount of carbon 14 at a cost of $10,000. It would have taken some 1,000 cyclotrons, at a cost of $100,000,000, to make the same amount. In 1958 almost 15,000 places in this country were using radioactive materials supplied by the Atomic Energy Commission.

Using Radioactive Materials

Carbon 14 is only one of many kinds of radioactive materials now sent out from Oak Ridge, but it makes up about one shipment out of every ten. Examples of other important shipments are radioactive phosphorus, iodine, calcium, sulfur, iron, zinc, and cobalt. Some of these radioactive materials are used as tracers, that is, as *tagged atoms.* When we say "tagged," we mean that the atoms

[1] This is a project by scientists to control the fusion of hydrogen atoms into helium.

[1] Remember that *radiation* means that an atom gives off particles like neutrons, protons, and electrons, and rays like gamma rays.

158 A Geiger counter traces radioactive iodine which is used in treating cancer of the thyroid gland.

USAEC

are radioactive and that this "radioactive tag" can be traced by a Geiger counter. If living things are fed tagged atoms, a Geiger counter can follow the atoms as they move through the bodies of the experimental plants and animals.

This tracing of tagged atoms gives scientists a chance to study how green plants make their food; how living cells are torn down and built up; how fuels may be improved. Already, by the use of tagged atoms, scientists have gained new knowledge of the way the human body works. For instance, the battle against disease, including cancer, has been speeded up (see charts at p. 288).

How Do Radioactive Materials Help Us Study Living Things?

The Atomic Energy Commission has built laboratories and hospitals in many parts of the country to find out how radioactive materials may be used to treat certain diseases. Radioactive materials are also sent to medical schools, hospitals, and other research centers for the same purposes. How are radioactive materials being used in the treatment of disease?

1. *Finding and removing tumors.* Radioactive substances mixed with a certain dye can be injected into a person who has a brain tumor. The dye and the radioactive substance are taken up by the tumor. By moving a Geiger counter over the head of the patient the tumor (which now has in it the tagged atoms of the radioactive substance) is found. Then the surgeon knows where to operate.

Sometimes a tumor appears on or just beneath the surface of a person's skin. If it is treated with certain radioactive atoms, the tumor may disappear.

2. *Measuring the activity of the thyroid gland.* The thyroid gland is important to the growth of the body. This gland is peculiar in that it picks

up almost all the iodine in the body. By feeding a person a small and harmless dose of radioactive iodine, a doctor can find out how well the thyroid gland is working. A Geiger counter held near the gland measures the time it takes for the gland to take up the radioactive iodine (Fig. 158). Also, it has been found that cancer tissue in the thyroid gland takes up radioactive iodine in large amounts. Some cancer growth may be checked this way.

3. *Measuring the speed with which the blood takes up certain food substances, like iron.* Harmless radioactive iron is fed to a person. Then a Geiger counter is placed near the pulse in the wrist. It has been found that in about 24 hours the iron has traveled from the mouth and passed through the intestines and into the blood. Since iron is used in treating some forms of the disease anemia, experiments like this one may lead to better methods of treating some kinds of anemia.

4. *Measuring the speed of life processes.* The use of tagged atoms has also given scientists a clue to the speed at which certain activities take place in the body. For instance, when a person is fed table salt with radioactive sodium in it, the salt is carried to the sweat glands and then brought to the surface of the body in *less than a minute.* No doubt other things your body does take place as fast or faster. Scientists are trying to find out by using tagged atoms.

5. *Studying how green plants make food.* By using radioactive materials as tracers, scientists are getting a much clearer picture of how green plants make food. First, plants are fed carbon 14 and minerals (made radioactive) that plants get from the soil. Then scientists trace the atoms and learn how green leaves make a starch out of sunlight, water, and carbon dioxide. They learn how the roots of plants pick up the chemicals from the soil. They also learn how these chemicals in turn are used in the bodies of the plants.

These studies have given us new knowledge about what kinds of substances plants need as they grow. In time scientists may learn how to speed up the growth of certain crops.

CALIFORNIA RESEARCH CORP.

159 Two kinds of oil separated by radioactive materials are flowing through this pipeline. One workman is using a Geiger counter. Why is the other waiting for a signal to turn the valve to switch the flow of oil into another tank?

Farmers in the United States spend half a billion dollars each year for fertilizers, that is, for the chemicals plants need for growth. Better knowledge of what plants need may help cut the cost and yet give us more and better fruits and vegetables. In 1958, the fertilizer industry saved us over $200,000,000 by finding the right kind of plant food for fertilizer.

How Do Radioactive Materials Help Industry?

Radioactive materials are among the most valuable tools of industry. Here are a few uses for them:

1. *Following the flow of oil through pipelines.* The same pipeline is often used to send out different kinds of oils, one right after another. Once it was hard to know just where one kind of oil in the pipeline ended and the next began. Some of the two kinds of oil often got mixed, which meant that it was wasted. Now a small amount of radioactive material can be put into the pipeline at the point where oil is changed from one kind to another. Then Geiger counters at the other end of the pipeline can be used to find out just where one kind of oil ends and the next kind begins. Sorting out the different oils when they reach the end of a pipeline means a large saving in oil and money.

2. *Measuring thicknesses of sheets of paper, plastic, glass, and metal.* Factories often get orders for sheets of material that must have a certain thickness. Any other thickness cannot be used. A radioactive gauge (measuring device) to measure thickness saves thousands of dollars a year.

The main parts of a radioactive thickness gauge are the element cobalt, which has been made radioactive, and a Geiger counter. Any change in the thickness of the sheet passing between the radioactive cobalt and the Geiger counter causes a difference in the number of clicks in the counter. In this way the thickness of the sheet is discovered within a thousandth of an inch.

3. *Finding flaws in metal castings.* If there is any break in a metal casting, such as the cast-iron block of an automobile engine or the base of a heavy machine, it can be found by using radioactive cobalt. The radioactive cobalt is placed on one side of the casting, and a photographic film on the other side. A darkening of the developed film shows the location of any cracks, since more radiation goes through these cracks and causes greater darkening of the film.

4. *Finding leaks in water pipes.* In many new houses the water pipes are buried in the concrete flooring. One owner of a new house found that his water bill was $60 per month, and his bill for heating water was $400 per month. He knew there was a leak in one of the hot-water pipes. No plumber could find the leak without tearing up the flooring, all of which could have cost a great deal of money. But the leak was quickly and easily found by putting a small amount of radioactive iodine into the main water pipe. A Geiger counter followed this radioactive flow of water beneath the floor until it reached the spot where the radioactive flow stopped. This was the place of the leak. Soon the pipe was repaired, at a small cost to the homeowner. Therefore, in the building industry we have another tool to save costly repairs.

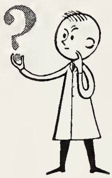
There are many other uses of radioactive materials in industry. By using

carbon 14 in the oil industry, scientists have been able to follow the changes as gasoline is made from crude oil. And by putting radioactive substances into oil pools at the bottom of oil wells, scientists can even trace the underground path of the pools.

In the steel industry, radioactive carbon and other radioactive elements can be used to find the amount of impurities in steel. As a result, better steel can be made.

These are but samples of how radioactive materials are being used. More and more uses in medicine, agriculture, and industry are being found each day. In 1958, their use in industry alone made a saving of over one billion dollars.

We are only at the beginning of our knowledge of atomic energy and its uses. Many scientists believe that your generation will live to see atomic energy used on a large scale as a common source of energy. You will benefit from this energy.



LOOKING BACK

Tool Words

Can you use these words in a sentence which will give their meanings? Use the glossary or refer to this chapter. DO NOT MARK THIS BOOK.

uranium	fall-out	Geiger counter
cyclotron	nuclear reactor	cosmic rays
atomic fission	breeder reactor	radiation
atomic fusion	atomic energy	helium
atomic pile	plutonium	radioactive material

Test Yourself

Copy the phrases in List A. Before the phrase write the letter of the word or phrase from List B that is most related to it. DO NOT MARK THIS BOOK.

List A

1. a source of uranium
2. a metal that takes up neutrons
3. atomic fission that produces usable atomic energy
4. an element as fissionable as uranium 235
5. radioactive dust in the air following an atomic explosion
6. an instrument that measures radiation from a radioactive source
7. the process that causes the sun's heat and light
8. heavy hydrogen

List B

a. neptunium
b. Geiger counter
c. pitchblende
d. iron
e. hydrogen 2
f. chain reaction
g. plutonium
h. radioactive iodine
i. fall-out
j. cadmium
k. atomic fusion
l. cosmic rays

GOING FURTHER

Committee Work

1. *Finding out about radioactivity.* Appoint a committee to report on the following: (*a*) the use of atom smashers, such as the cyclotron; (*b*) atomic fission; (*c*) atomic fusion; (*d*) cosmic rays.

2. *Uses of radioactivity.* Appoint a committee to report on the uses of atomic energy in: (*a*) medicine; (*b*) agriculture; (*c*) industry.

3. *Defense against the atomic and hydrogen bombs.* Appoint a committee to report on the activities of your local Civil Defense Committee. Perhaps you can ask the chairman to give a report to the class.

Put on Your Thinking Cap

1. On March 27, 1953, a Geiger counter in a high school classroom in Brookline, Mass., was turned on to show how cosmic rays could be discovered. Instead of the slow uneven clicks caused by cosmic rays, the counter clicked very fast. No radioactive material was near the counter. During the first part of March, atomic explosions had been set off in Nevada, almost 3,000 miles away. The general direction of the winds had been westerly, that is, traveling from west to east.

What kind of radiation was it that the Geiger counter picked up? What is it called?

2. In September 1949, President Truman announced that recently there had been an atomic explosion in the U.S.S.R. His statement mentioned that the method of making an atomic bomb was widely known, and that foreign research into atomic energy would come up to our present knowledge in time.

In January 1950, the President announced that the United States would make hydrogen bombs.

On November 1, 1952, the United States exploded the first hydrogen bomb.

In August 1953, the U.S.S.R. announced a hydrogen bomb explosion.

a. What instruments may have been used to detect an atomic explosion in the U.S.S.R.?

b. Why had it been expected that other nations would soon be able to make atomic and hydrogen bombs?

c. How do these events point out the need for control of atomic energy? What kind of controls should we have?

Adding to Your Library

1. *Peacetime Uses of Atomic Energy* by Martin Mann, Crowell, 1957.

2. *There's Adventure in Atomic Energy* by Julian May, Popular Mechanics, 1957.

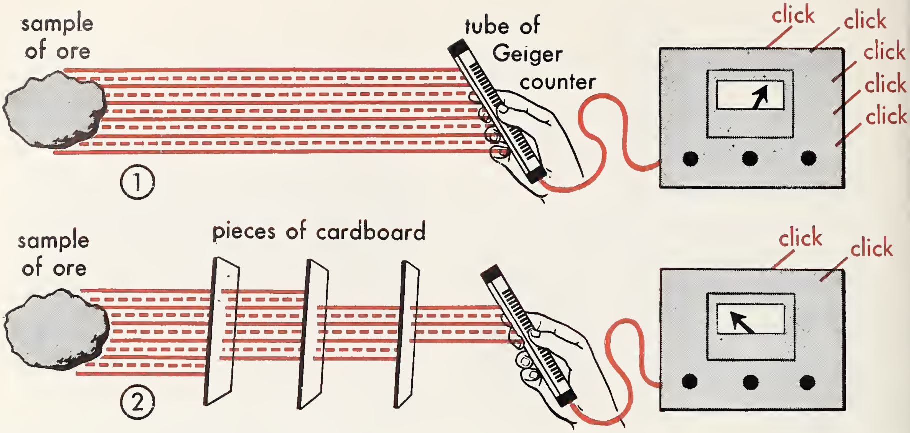
3. *Atoms for Peace* by David O. Woodbury, Dodd, 1958.

4. *The Tenth Wonder, Atomic Energy* by Carleton Pearl, Little, 1956.

5. *Atoms for the World* by Laura Fermi, University of Chicago Press, 1957. The International Conference on the Peaceful Uses of Atomic Energy met in Geneva, August 1955. Scientists from many parts of the world met and shared what were once atomic secrets. Mrs. Fermi tells what happened on this historic occasion.

6. *The Man in the Thick Lead Suit* by Daniel Lang, Oxford University Press, 1954. All about the atom bomb, uranium, and radioactivity.

7. Those who wish to read further about the atomic and hydrogen bombs and the uses of atomic energy should write to the United States Atomic Energy Commission, Washington, D.C., for the free booklet, *Selected Readings on Atomic Energy.* It lists not only the available publications of the Atomic Energy Commission, but also all books published to date on atomic energy.



160 Pieces of cardboard between the radioactive material and the tube of the Geiger counter prevent the counter from detecting some of the particles thrown off by the material. Why is shielding used on atomic piles? *Project:* If your school has a Geiger counter, try to find out the radioactivity of common materials — coal, iron, a radioactive watch, and other materials.

A Bit of Research

If you have a Geiger counter in your school laboratory or can get one from your local Defense Committee, do these experiments:

1. Turn on the switch of the Geiger counter. Make a note of the number of clicks and how often they start and stop. What causes the clicks?

2. Have a student bring the *luminous* dial (one that glows in the dark) of a wrist watch close to the tube of the Geiger counter. Make a note of the number of clicks. What causes the increase?

3. If your school has a sample of carnotite (KAHR-nuh-tyte), an ore of uranium, or if you can get a sample from a scientific supply company, bring the sample near the tube of the Geiger counter. Make a note of the rate of increase of the clicks as you move the sample toward the tube. Make a note of the rate of decrease of the clicks as you move the sample away from the tube. Now move the sample two inches away from the counter tube. Place some pieces of cardboard, one at a time, between the sample and the counter tube. Make a note of the number of clicks as each piece of cardboard is added (Fig. 160).

Write up this bit of research in your science notebook with a conclusion as to why shielding is used around nuclear reactors.

Careers for You

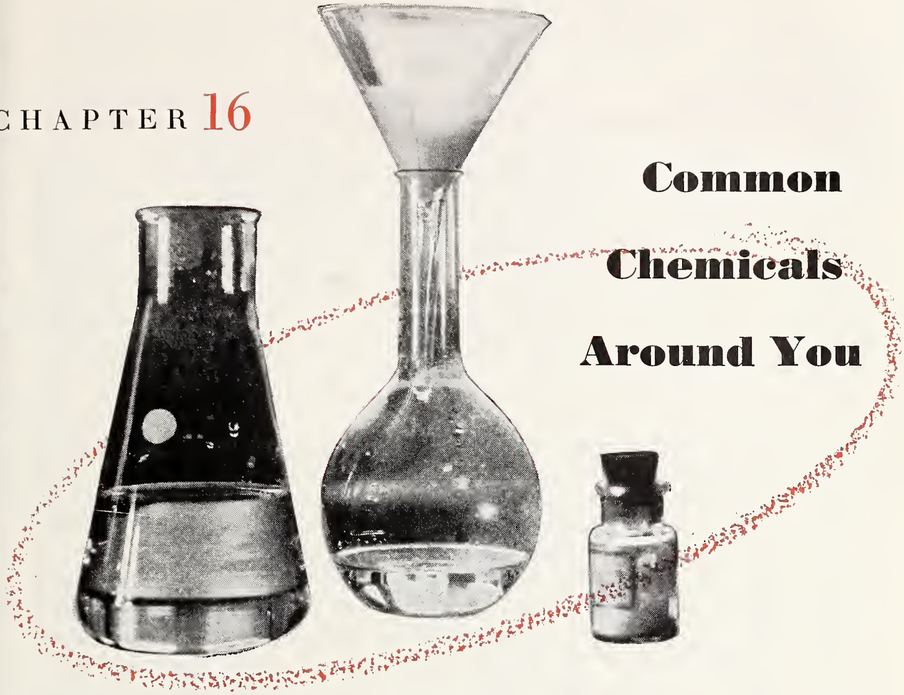
Do you want to be a *nuclear scientist?* a *specialist* in the use of radioactive materials in industry? a *doctor* who might discover new ways of fighting disease by the use of tagged atoms? a *biologist* skilled in the use of radioactive materials in growing better plants and animals?

These are but a few of the opportunities that await you. Perhaps you may decide right now that your future work will be in the field of atomic energy.

Civil Defense — a job for everyone. Have you signed up for a Civil Defense job in your town, village, or city? Go to your Civil Defense office as soon as you can and see whether you can be of service. This is a good way of serving your community.

CHAPTER 16

Common Chemicals Around You



Laboratory apparatus. What does it represent? An experiment being done by a student, or a valuable new substance? It could be either. There are many uses for the common chemicals around you.

IN a Montana mine, every two minutes a huge shovel scoops up ten tons of bluish-colored earth and dumps it into waiting trucks. The trucks carry the blue earth to a nearby plant. The hot furnaces in the plant change the blue earth into a useful metal.

Two thousand miles away in Texas a pipeline runs out into the ocean. Every day millions of gallons of sea water rush through the pipe into huge, round tanks. There the sea water is treated with chemicals. After a while the sea water is pumped out of the tanks back into the ocean. But it has left in the tanks some of the valuable materials it contained.

On the outskirts of a busy city in Massachusetts a sign above a factory reads: LIQUID AIR. Inside can be heard the hum of machinery. Pumps move back and forth. Air — the air that you breathe — is made so cold by this machinery that it turns into a liquid like water. Then this liquid air is separated into pure gases — oxygen, nitrogen, and others.

What connection have these activities with each other? In the first, a

TABLE 9 Most Abundant Elements in Land, Water, and Air

The Earth's Crust (Percentage by Weight)		*Oceans, Rivers, Lakes (Percentage by Weight)*		*The Air at Sea Level (Percentage by Volume)*	
Oxygen	46.7	Oxygen	85.	Nitrogen	78.
Silicon	27.7	Hydrogen	10.7	Oxygen	21.
Aluminum	8.1	Chlorine	2.1	Argon	0.94
Iron	5.0	Sodium	1.2	Carbon dioxide	0.03
Calcium	3.7	Magnesium	0.14	(Note: Carbon dioxide is a compound of carbon and oxygen. It is placed here because of its importance to green plants. See Chapter 18.)	
Sodium	2.7	Sulfur	0.09		
Potassium	2.6	Calcium	0.05		
Magnesium	2.1	Potassium	0.04		
Titanium	0.62	Bromine	0.008		
Hydrogen	0.14	Carbon	0.002		

bluish-colored rock containing copper is being dug from the earth. In the second, magnesium is being taken out of sea water. In the third, oxygen is being separated from liquid air. These three widely different activities are alike in one way. In each a useful substance is being removed from the crust of the earth, the waters of the earth, or the earth's great covering of air.

Of course, not all materials making up the world are as valuable as copper, magnesium, or oxygen. No matter how many our wants are, the substances that satisfy our wants and make our life richer come from the earth, its water, and its air. In this chapter, you will learn what some of these things are. You will explore the earth, the waters of the earth, and the air surrounding the earth. You will find that no matter where you go or what you do, you are dependent on the chemicals of the earth's great storehouse.

Beneath Your Feet

Scientists have discovered that all matter in the world is made up of 92 elements. (Ten more, as you know, were made by atomic scientists.) Some of these elements are very scarce. Others may be found almost anywhere in mixtures or in compounds. (See Table 10.)

You can see by Table 9, above, that just eight of the 92 elements make up almost the entire earth; the other 84 make up only 1½%. Of these 84 elements, 77, such as gold, silver, and uranium, make up less than 0.1% of the whole earth! These figures show why some elements are rare and hard to find. But these elements must be found. Let us hunt for some of them.

FROM ELEMENTS TO MINERALS AND ORES

Do you know how most gold rushes start? Someone finds particles of gold in a stream bed or in a rock. The word gets around. From that time on, it is everyone for himself. One good thing about searching for gold is that gold hunters (prospectors) know what to look for. Gold is found free in nature; it is not combined with other elements. All but a few elements in the earth are found

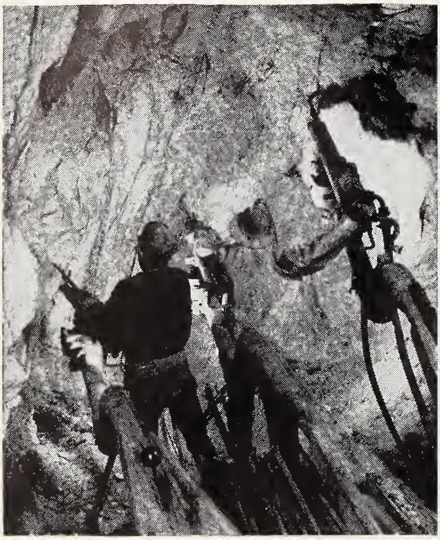
TABLE 10 Some Common Elements

Name	*Appearance*	*Common Way or Ways Element Occurs*	*Symbol*	*Atomic Weight*
Aluminum	Light, shining, grayish-white metal	Combined with oxygen in clay	Al	27.
Bromine	Reddish-brown liquid	Combined with magnesium in salt water	Br	80.
Calcium	Grayish-white metal	Combined with carbon and oxygen in marble	Ca	40.
Carbon	Sparkling (diamond) Black (coal, graphite)	By itself as coal, diamond, graphite	C	12.
Chlorine	Greenish-yellow gas	Combined with sodium in table salt	Cl	35.5
Copper	Shining reddish-brown metal	By itself and in ores of copper	Cu	63.6
Gold	Yellow metal	By itself	Au	197.
Helium	Colorless gas	By itself in natural gas	He	4.
Hydrogen	Colorless gas, lightest known	Combined with oxygen in water	H	1.
Iodine	Salty gray solid	Combined with sodium in seaweeds	I	127.
Iron	Grayish-white metal	Combined with oxygen	Fe	56.
Lead	Bluish-white metal	Combined with sulfur	Pb	207.
Magnesium	Light silvery-white metal	Combined with chlorine	Mg	24.
Mercury	Heavy silvery-white liquid	Combined with sulfur	Hg	200.
Nitrogen	Colorless gas	By itself in air	N	14.
Oxygen	Colorless gas	By itself in air and combined with hydrogen in water	O	16.
Platinum	Heavy white metal	By itself	Pt	195.
Potassium	Soft silvery-white metal	Combined with oxygen in wood ashes	K	39.
Radium	Grayish-white metal	In ore called pitchblende	Ra	226.
Silver	White shining metal	By itself and also combined with sulfur	Ag	108.
Sodium	Soft silvery-white metal	Combined with chlorine in table salt	Na	23.
Sulfur	Yellow solid	By itself and combined with metals	S	32.
Tin	Soft white metal	Combined with oxygen	Sn	119.
Uranium	Heavy white metal	Combined with oxygen	U	238.

combined with other elements. The compounds they form make up most of the minerals found in the earth today. A *mineral* is any substance found naturally in the earth's crust. For instance, sand and clay, as well as the salt in sea water, are minerals.

Now look again at Table 10. Would you expect the most common elements to be part of the most common minerals? That's just what happens. Silicon and oxygen are found combined everywhere as sand or as parts of clay. Clay and sand and rock particles make up most of the earth's soil.

The minerals from which we get useful metals are called *ores*. A bluish-



ANACONDA COPPER MINING CO.

161 Deep in a copper mine, these men are drilling holes into a bluish-colored vein of copper ore to get it ready for blasting. Why is copper ore different in color from copper?

colored ore of copper is being dug from a mine in Fig. 161. Certainly this blue ore of copper is nothing like the copper used in a penny or in the wires that bring electricity into your home. You won't find most metals in the pure state, nor will their ores look as if they contained the metal. For example, you will not find pure lead if you go looking for that metal. It will probably be part of a heavy, shiny black crystal. Pure iron is never found by itself. It is usually part of a reddish or purple ore. The shiny white metal, aluminum, comes from a grayish-white clay. Mercury, the silvery-white liquid in the bulb of your thermometer, is found in a heavy, soft, red earth.

So it goes. Unless the element is found by itself, like gold or platinum, it is part of a mineral that is entirely different in appearance. These minerals are everywhere in the earth's crust, and even in ocean water and in the water you drink.

WATER — A HANDY FRIEND

This water you take so much for granted is one of the most important chemicals on this earth. It is important to the chemist and to you. Without water life could not go on, because every part of your body contains liquid. Most important, water can hold other chemicals, that is, dissolve them in itself. When water dissolves sugar, you cannot see the sugar in the water. The water is just as clear as it was before. A substance (such as sugar) that dissolves in a liquid (such as water) is called *soluble.* Likewise, the mixture of water and a dissolved substance is called a *solution.* The oceans of the earth are solutions of minerals and water.

Why Is the Ocean Salty?

Whenever water comes in contact with soil, it takes up or dissolves some minerals. Even your pure drinking water has some minerals in it. Take an absolutely clean saucer or glass and fill it with tap water. Let the saucer stand in a warm place for a few days until all the water has evaporated, that is, gone into the air. The film you see in the bottom of the saucer is made by the small amount of mineral matter that is ordinarily dissolved in tap water.

In the same way, the hard material which forms on the bottom inside your teakettle comes from minerals. These have settled out of the boiling, over a long period of time. A city's

water pipes may become clogged by the minerals from millions of gallons of water flowing through them.

When we say that the ocean is salty, we mean that it has in it a large amount of dissolved minerals. When water evaporates from the surface of an ocean, or a lake without an outlet, the minerals are left behind. This is the reason for the great amount of salt in the Great Salt Lake in Utah and in the Dead Sea between Israel and Jordan.

Dissolved Minerals Are Valuable

Three-quarters of the earth's surface is covered by oceans. Every glass of this sea water has in it about a teaspoonful of salt. This is mainly table salt (sodium chloride). But there are also small amounts of other compounds such as magnesium chloride and magnesium bromide. It is said that, if all the minerals could be taken from the oceans, they would cover North and South America with a blanket 400 feet deep.

In 1 cubic mile of ocean water there are about 160 million tons of dissolved minerals.[1] In these dissolved minerals more than half of all the known elements have been found, even gold. We do not get gold from sea water because it would cost more to get it from the sea than to mine it from the earth.

However, 1 cubic mile of sea water has in it about 5 million tons of magnesium and 1 million tons of *bromine* (BROH-meen). A way to get these two elements from sea water was found 30 years ago. For this purpose millions of gallons of sea water are pumped daily through plants like the one mentioned at the beginning of this chapter.

About 200,000 tons of magnesium and 35,000 tons of bromine are used in the United States each year. Magnesium, a light metal, is used in building airplanes. You may even have a magnesium ladder in your home. Bromine is used in making antiknock gasoline and in chemical industries. Nearly all the bromine and much of the magnesium come from minerals of the sea.

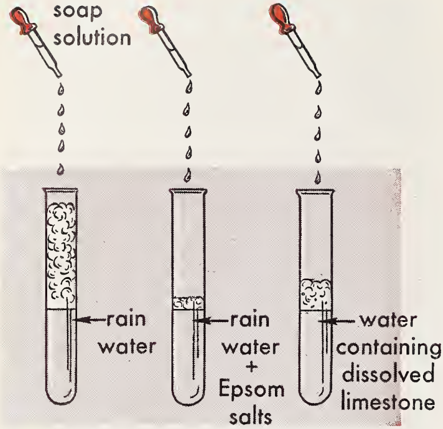
Dissolved minerals have still other values. They help to give drinking water its flavor. Most mineral matter in drinking water is perfectly harmless; in fact, some is beneficial. Small amounts of a mineral with iodine in it are in certain waters. The iodine prevents one kind of simple goiter, a growth of the thyroid gland, which is found in the throat. In some sections of the country water contains compounds of *fluorine* (FLOO-er-een), believed to help prevent tooth decay.

Hard Water

Water in which soap does not lather easily is called *hard* water. Hard water has in it salts of magnesium and calcium. Soap does not dissolve in hard water, with the result that much of its cleansing action is lost. Would you call sea water hard water? It certainly is. Ordinary soap feels like grease when it is used with sea water.

To show how hard water acts on soap, fill two test tubes one-third full of rain water or distilled water. These are soft waters with little or no minerals in them (Fig. 162). Fill a third test tube one-third full of

[1] A cubic mile is a square mile of water a mile deep.



162 Does it take more soap to make suds when using rain water or when using water with dissolved minerals in it? *Project:* Try this experiment with different kinds of soaps and drinking water from different sources.

limewater. Using a medicine dropper, allow five drops of a liquid soap to fall into one of the test tubes of rain water. Shake it to form suds. Now add a pinch of magnesium sulfate (Epsom salts) to the second test tube of rain water or distilled water. Add five drops of soap solution and shake it. Do you get as much suds as in the first tube? Would your expenses for soap be greater when using hard water or when using soft (rain) water?

Now blow your breath carefully through a straw into the test tube of limewater. The carbon dioxide of your breath reacts with the limewater to form bits of calcium carbonate, really a form of limestone. If you keep on blowing in carbon dioxide, the milky color will disappear. A soluble compound is formed, and this makes the water hard. How many drops of soap must you add to this test tube to get suds equal to that in the first test tube containing rain water? You will find that you have to add three or four times as much soap. What do you conclude about the cost of using soap in regions where the water is hard, like the water you have been working with? Is the cost higher or lower? Why?

How would you solve the problem of washing clothes in hard water? Wouldn't you try to soften the water? Wouldn't you try to add something to it that would stop the action of the magnesium or calcium salts? That is just what many housewives do. Washing soda or borax or a little ammonia added to hard water will help. There are other commercial water softeners, which take out the magnesium and calcium salts. They are often used in regions where the water is extremely hard.

Limestone Caves and Hard Water

You may have heard of or visited the Mammoth Cave of Kentucky, the Luray Caverns of Virginia, or the Carlsbad Caverns of New Mexico. If you have, no doubt you have wondered how such immense caverns were formed.

You know that a great deal of water is found beneath the surface of the earth. Much of it has carbon dioxide in it. During many past centuries, this underground water bearing carbon dioxide had dissolved the limestone far below the earth's surface. As this hard water dissolved the limestone, it left great holes where the limestone once was. These open spaces form the caves we know today.

When underground hard water

evaporates from the roofs or floors of these caverns, it leaves behind the dissolved limestone and other minerals in the water. As this happens, the limestone often builds up into beautiful shapes like icicles and columns (Fig. 163).[1] The limestone icicles hang from the roofs of the caves. The columns stand up from the floors. Their beauty attracts thousands of visitors.

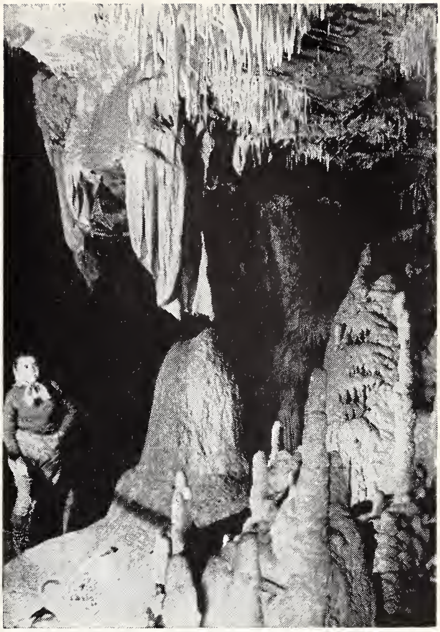
Handmade Solutions

Of course water dissolves many things besides limestone. It dissolves some substances better than it does others. Let us see how this works.

Fill two test tubes one-third full of water. Now fill a third tube with table salt and a fourth tube with magnesium sulfate (Epsom salts). These we will call your supply tubes. Now add about a teaspoonful of table salt from your supply tube to one of the tubes containing water, and add a teaspoonful of magnesium sulfate to the other tube containing water. Shake well.

Add the salts and shake until you can dissolve no more salt or magnesium sulfate. You have reached a point where the solution in one test tube is *saturated* (SACH-er-ayt-id) with the table salt. In the other tube the solution is one that will hold no more of the dissolved substances at that temperature. Now examine the levels of the table salt and the magnesium sulfate in the supply test tubes. Which one is the lower? Which of the two substances dissolves more readily?

[1] The limestone icicles hanging from the roof are called *stalactites* (stuh-LAK-tyts). The columns built up from the floor are called *stalagmites* (stuh-LAG-myts).



PENNSYLVANIA DEPT. OF HIGHWAYS

163 A visitor admires the beauty of limestone formations in a large cave. Why do some of the formations hang from the ceiling while others stand up from the floor?

Next, take the test tube containing the saturated solution of magnesium sulfate and heat it. Now try to dissolve more magnesium sulfate in the solution. Are you successful? You will be, for as you raise the temperature, more magnesium sulfate will be dissolved.

You have seen by this activity that some substances, like table salt, do not dissolve in water as readily as do other substances, like magnesium sulfate. You have shown that there is a point — the saturation point — beyond which no more of a substance can be dissolved at a certain temperature. And you have seen that if you increase the temperature, a larger

amount of the substance can be dissolved. This is true of most soluble substances.

Gases can be dissolved in liquids; for example, carbon dioxide is dissolved in ginger ale and soda pop. With gases, raising the temperature of the solution lowers the amount of a gas you can dissolve — just the opposite of what happens with most solids.

How does all this apply to your daily life? A scientist, a doctor, a druggist, and even a housewife must know what substances dissolve easily and what substances do not dissolve or are hard to dissolve. In making medicines or solutions, they must know or be able to find the saturation point of a solution. Then they must know that by heating water they can usually dissolve more of a solid substance in a shorter space of time.

Suspensions

Many solids that do not dissolve in water are still carried by water. These solids are plainly seen, as in a glass of muddy water. Muddy water is a *suspension*. Familiar suspensions in your home are fresh milk, gravy, starch in water, and mayonnaise. Many suspensions, such as muddy water, settle if they are left standing.

Suspensions play a great part in changing the earth's surface. The tremendous amount of soil carried in suspension by the Mississippi River builds the river out 250 feet farther each year into the Gulf of Mexico (Fig. 72). In a similar way, the Nile and the Danube rivers increase their length 13 feet each year. Whenever soil is carried from one spot to another on the earth's surface, suspensions are mainly responsible.

Absolutely Pure Water

How can we get water with nothing dissolved or suspended in it?

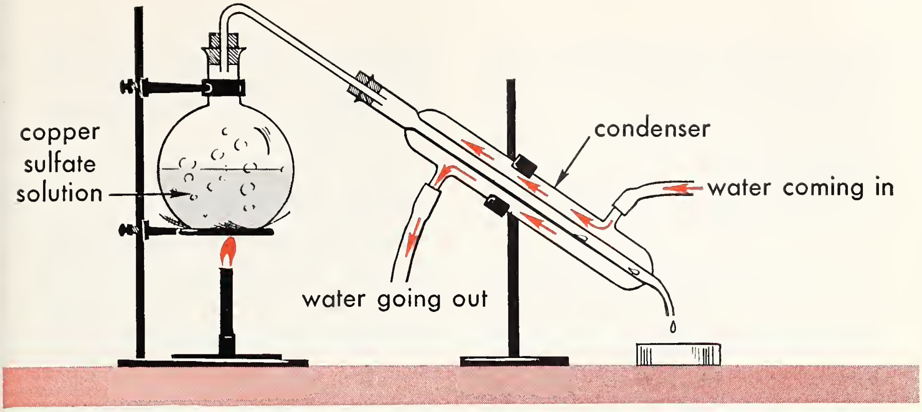
Chemists, doctors, druggists, manufacturers, science teachers, and science students, to mention but a few, need water free from all dissolved material. We can get this by boiling water that has impurities in it. The steam that is formed contains no harmful germs and no dissolved minerals either. The steam is collected and cooled, and finally forms water again. This process of freeing water from its impurities is called *distillation* (dis-tih-LAY-sh'n).

No doubt your school has a distillation apparatus similar to the one in Fig. 164. You may see how it works by filling a large flask one-half full of blue copper sulfate solution. Now set it up as shown in the figure. Boil the copper sulfate until a colorless liquid drips from the condenser tip into the beaker. The water, free from impurities such as the copper sulfate, is called distilled water.

AIR — AN INVISIBLE OCEAN

"I won't believe it unless I see it!" How many times have you heard someone say that? Strangely enough, many people used to believe that air was not a real substance because they could not see it. In fact, many ancient Greeks did not believe that air was a real substance until one of their famous men, Anaxagoras (an-ak-SAG-uh-russ), fell down on a blown-up goatskin bag.

It happened this way. In those



164 Boiling a solution of blue copper sulfate in the flask produces colorless, pure water which drips from the end of the condenser. How does distillation rid water of impurities?

days blown-up goatskins were used as floats to support rafts. Anaxagoras was carrying a freshly blown-up skin for his raft when he stumbled on the rocky beach and fell. His fall was cushioned by the blown-up bag, and he was not hurt. This started Anaxagoras thinking of air as a real substance. His reasoning, which has come down to us, was as follows: "If there was nothing in the bag, I would have been hurt. If the bag had been filled with moss, a real substance I could pick in the woods, I would not have been hurt. But it was filled with air and still I wasn't hurt. Therefore air, like moss, must be a real substance."

Today we know how right Anaxagoras was. An automobile rides on the cushion of air in its tires. Air holds up a 150-ton airplane in flight.

The great, invisible ocean of air around you is a real substance.

The Earth's Air

No other planet around our sun has air just like the air surrounding the earth. Astronomers tell us that there is not enough oxygen in the air of other planets for life like ours. For example, the air on Mars is mostly carbon dioxide and nitrogen; Jupiter's air is mostly ammonia gas, and Saturn has air that contains methane (METH-ayn), an explosive gas found in coal mines. You can understand that you could not breathe the air on any other planet and live.

What Is Air Made Of?

People who lived more than 175 years ago did not know what air was made up of. It was not until 1774 that the great English chemist Joseph Priestley found that air had oxygen in it. Today we know that air has other gases besides oxygen. For example, air has neon, a gas used in advertising signs to cause the red glow. Air also has argon and nitrogen, gases that fill nearly 2 billion electric light bulbs made yearly in the United States. About 1% of air is made up of argon, neon, and a few other gases. Most of the rest of air — about 79% — is nitrogen, and almost 20% is oxygen. Water vapor

and a small amount of carbon dioxide, as well as dust particles, are always found in air.

OXYGEN — SUPPORTER OF LIFE

What would happen if the air were pure oxygen? With every breath you would draw in five times as much oxygen as you breathe now. Immediately you would feel very, very active. You could probably run faster than you had ever run before. If you kept on breathing pure oxygen (in our imaginary air) you would die. However, before that happened, someone would have struck a match somewhere. Entire cities and towns would burn up in a twinkling; even iron would burn. Probably the whole world would soon be lifeless and barren.

The large amount of nitrogen in the air makes the oxygen much thinner than it would be if air were pure oxygen; thus we are able to breathe and live. Nitrogen is called an inactive gas; oxygen, an active gas. That is, nitrogen does not react (combine chemically) with anything at ordinary temperatures. Oxygen reacts with many things.

As you read in an earlier unit, all living things use oxygen. Not only do they take in oxygen when they breathe, but they also use it to burn (oxidize) food in their cells. In this way the food is used for energy and growth. Oxygen is also used up in other ways, as you know from your earlier reading. For instance, a fire could not burn without oxygen. Why is it that our supply of oxygen was not used up long ago? For the present, you need only know that *green plants* give off oxygen as they make their own food. The complete story of how green plants make fresh oxygen is left to Unit 6.

Getting Pure Oxygen

For use in industry, pure oxygen is taken out of the air. First, air has to be made into a liquid by cooling it. When air is cooled to 312° below 0° F. (344° below the freezing point of water), it becomes a liquid, bluish in color. If liquid air is cooled to 362° below 0° F., it becomes a hard solid.

Liquid air is so cold that it changes the properties of many things that are placed in it. A rubber ball dipped in liquid air and thrown against a wall will shatter like glass. A banana becomes so hard that it can be used as a hammer to drive nails. An iron pan, when placed in liquid air, becomes so brittle that it can be broken by hand. If a finger were placed in liquid air, it would freeze solid.

Liquid air has in it the same amounts of gases that are in ordinary air. These gases are, of course, now in the liquid state. When liquid air evaporates, the liquid nitrogen evaporates more quickly than the other liquid gases. Thus the liquid air left becomes richer and richer in oxygen. Argon, neon, and other rare gases then evaporate separately. Thus oxygen that is about 99.5% pure is left behind. In this way, oxygen as well as the other gases in air can be separated in the pure state.

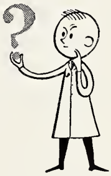
What Are the Uses of Pure Oxygen?

Some substances, such as *acetylene* (uh-SET-uh-leen), when mixed with pure oxygen under pressure and

burned, give a flame hot enough to cut metals or to weld one metal to another. Such welding outfits are part of the equipment of most automobile repair shops. Large amounts of pure oxygen are used in this way.

As you may remember from your earlier reading, at high altitudes the air is thinner and has less oxygen than does air at sea level. Pilots in high-flying planes use oxygen tanks for breathing. Without this extra oxygen, pilots would quickly lose consciousness. Oxygen tanks are also carried by mountain climbers. When Sir Edmund Hillary and Tenzing Norkay climbed Mt. Everest in May, 1953, they carried oxygen tanks. Without this extra oxygen to breathe, they could never have been the first persons to reach the top of the highest mountain in the world. Hospitals also use oxygen tanks to help sick people who have difficulty in breathing. A covering, called an oxygen tent, into which flows air rich in oxygen, is placed over the patient. With each breath he gets far more oxygen than he could get from ordinary air.

You now know something of a few of the chemicals around you. You have learned how some of them are used. But there are a great many materials in the earth's crust that are not found in everyone's back yard. You probably will not find valuable ores such as ores of uranium, mercury, lead, or iron even within a great distance of your home. You probably will not find gold, silver, copper, or oil in your back yard. How some of these substances are taken from the earth, treated, and used will be the subject of the next chapter, "The Wealth in the Earth's Crust."



LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

solution	mineral	suspension
dissolved	ore	soft water
saturated solution	hard water	distillation

1. will hold no more of the dissolved substance at a certain temperature
2. a mineral from which we get a useful metal
3. water in which soap makes suds easily
4. water containing small particles of a substance you see
5. a mixture of water and a dissolved substance
6. any substance occurring naturally in the earth's crust
7. water in which soap does not lather well
8. soluble in water, thus making a solution
9. a method of getting pure water

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. Useful . . . are procured from ores.
2. Any substance occurring naturally in the earth is called a . . . .
3. Underground water containing . . . causes the making of caves.
4. Water having particles of soil in it is called a . . . .
5. Water having certain minerals in it is called . . . water.
6. A . . . solution of a substance is one that has all the dissolved substance it can hold at a certain temperature.
7. Water that carries insoluble substances is called a . . . .
8. . . . is a method for making pure water.
9. Neon, the gas that causes the red glow in advertising signs, is taken from . . . air.

GOING FURTHER

In the Laboratory

1. *Making a solution.* Dissolve a crystal of copper sulfate in one-half test tube of water. Now shake up a teaspoonful of soil in another test tube half-filled with water. Hold both test tubes up to the light. Which one is clear and transparent? Let both test tubes stand for five minutes. Which one has an even distribution of color? Which one settles on standing? Now write a clear statement to show that you know what a good solution is.

2. *Recovering a dissolved solid from a solution.* Pour the test tube of copper sulfate solution into an evaporating dish and place the dish on a hot plate or over a lighted Bunsen burner. Allow the dish to stand until all the water has boiled away. What is left in the bottom of the dish? How would you get back silver nitrate dissolved in water?

3. *A chemical reaction in solution.* Stir a few small crystals of table salt and silver nitrate together on a paper. Is there any evidence of chemical change? Now dissolve a few crystals of table salt in one-half test tube of water. Do the same with a few crystals of silver nitrate in another test tube. Pour the solution from one test tube into the other. What evidence of chemical change is there? What do you conclude concerning the use chemists make of solutions to produce a chemical reaction?

4. *Making oxygen.* Fill a small beaker one-quarter full of hydrogen peroxide. Add to it one-half teaspoon of powdered manganese dioxide. The manganese dioxide will cause the hydrogen peroxide to give off oxygen very rapidly. After a moment, light a wood splint and blow out the flame. Put the glowing end of the splint into the beaker close to the surface of the liquid. Does the splint burst into flame? Do substances burn more rapidly in pure oxygen than in air? What would happen if the air were pure oxygen?

Put on Your Thinking Cap

1. The maker of an electric steam iron advises purchasers to use only distilled

water in the iron to make steam. What is his reason?

2. What would you do to find out if a glass of clear water has dissolved substances in it? How would you make the water pure if it had such substances in it?

3. You have dissolved all the copper sulfate you can in a certain amount of water at room temperature. What must you do to dissolve more copper sulfate?

4. Give the reasons for the following:

a. Large rivers extend themselves out into the ocean.

b. We can get pure oxygen from liquid air.

c. Most metals are not found in the pure state.

Adding to Your Library

The following books are for your reading pleasure. They will give you a better understanding of the things that interested you in this chapter.

1. *All About Our Changing Rocks* by Anne Terry White, Random, 1955. Some rock is shiny like glass, some is specked and sparkling. How have these rocks been formed and how can we identify them? You will learn from this interesting book and its many drawings.

2. *Water for America* by William R. Van Dersal and Edward H. Graham, Walck, New York, 1956. The story of Water Conservation told with many photographs.

3. *All About the Desert* by Sam and Beryl Epstein, Random, 1957. Why are deserts dry? How dry is a desert? These and other questions about the fruit of the desert, the desert cowboy and special deserts are answered in this book.

4. *Dust Bowl* by Patricia Lauber, Coward, 1958. This is the story of man on the great plains.

5. *Rocks and Their Stories* by Carroll L. and Mildred A. Fenton, Doubleday, 1951. There are many pictures of different kinds of rocks and minerals in this book. The chapter "Knowing Minerals" is particularly good.

6. *The Sea Around Us* by Rachel L. Carson, Oxford University Press, 1951. A most fascinating story of the sea and what it contains. Be sure to read this book.

7. *The Story of Caves* by Dorothy Sterling, Doubleday, 1956. This is a simple, interesting book about how caves formed, how to find a cave, and what you can expect to find in a cave.

A Bit of Research

Some of the minerals in tap water are sulfates and chlorides. Find out if your tap water has sulfates in it by adding a few drops of a dilute solution of barium chloride to a test tube one-half full of tap water. A white, cloudy formation of barium sulfate will appear if sulfates are present. To find out if your tap water contains chlorides, add a few drops of silver nitrate solution to a test tube one-half full of tap water. A white, cloudy formation of silver chloride that will dissolve in ammonia water will appear if chlorides are present.

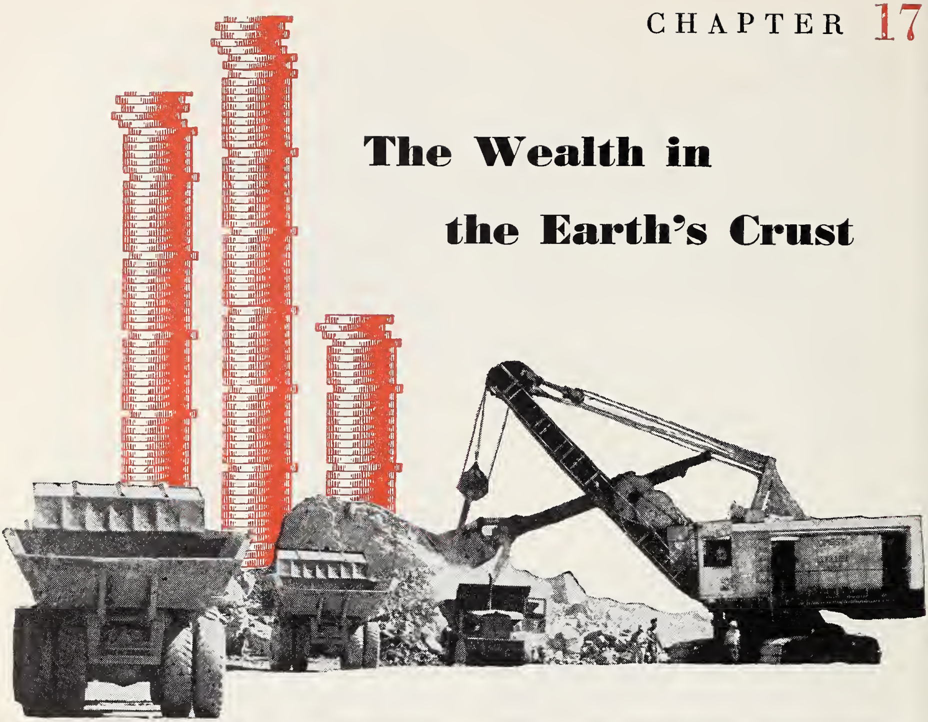
Using the apparatus in Fig. 164, distill some tap water and test the distilled water for minerals. Is the distilled water free from minerals? What do you conclude is the best method for getting absolutely pure water?

Careers for You

Nearly every business or manufacturing plant deals in some way with the chemicals in the earth's crust. Hundreds of men and women are needed at all times as *chemists*, *laboratory assistants*, and *technicians* in laboratories. There are also opportunities for field work as *geologists*, for making surveys of land and for finding out what is in mineral deposits as well as ores.

CHAPTER 17

The Wealth in the Earth's Crust



What is this wealth? Iron, sulfur, copper, aluminum, coal, oil — not just gold or silver. What would your life be like if our country did not have this wealth in the earth's crust?

"*Seek and you shall find.*" Perhaps that was the one leading thought young Charles Hall had in mind one morning in the year 1886. Certainly he had been seeking long enough. He had been patient. He had been thorough. Now at last he thought he had found what he sought.

On this particular morning, Charles Hall and his sister Julia were standing in front of a furnace Hall had built in his father's woodshed in Oberlin, Ohio. Hall pushed an electric switch. Into the bottom of a frying pan lined with carbon trickled a thin stream of silvery-white, molten aluminum. When the current was shut off, the aluminum cooled quickly into a few tiny balls. These balls of aluminum, the first to be made in America, are called the jewels of the great aluminum industry.

METALS AND THEIR ALLOYS

Charles Hall was the first to make aluminum cheaply from an ore of aluminum. The ore is made up of

the substance aluminum oxide and other materials. Hall separated aluminum from aluminum oxide by using electricity (Fig. 165). Before he found how to get aluminum from its ore, aluminum cost $542 a pound. Today aluminum sells for about 15 cents a pound.

Besides being cheap, aluminum is a very light, strong metal that does not rust easily. This is why it is used in producing airplanes, automobiles, roofing, storm windows, pots and pans, and hundreds of other things. In this chapter you will discover how important aluminum and other metals are to our way of life.

Iron from Iron Ore

The most important and useful metal in the world today is iron. Iron is necessary for the world's work. It is used in making steel. Without iron or steel, our way of life could not go on.

To get iron from iron ore, a tall furnace 100 feet high is built and lined with special brick (Fig. 168). It is called a blast furnace because blasts of very hot air are blown in at the bottom. In the blast furnace the iron ore yields its iron metal.

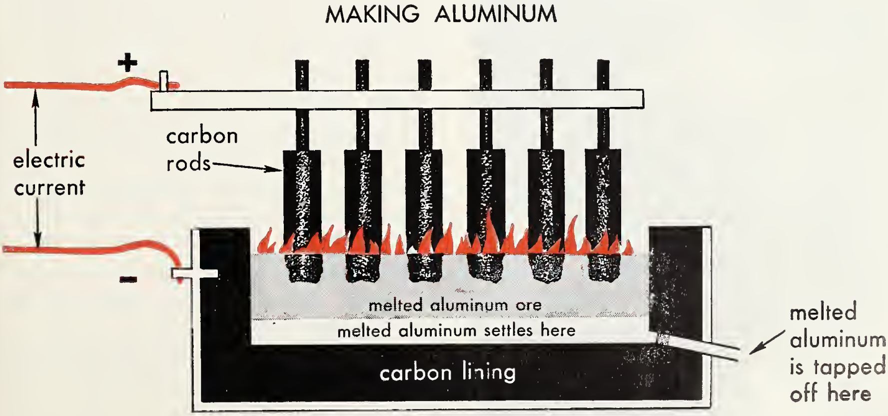
The iron flows out as a liquid at the bottom of the furnace. It is then poured into molds and cools into solid bars called "pigs." Once started, a blast furnace is kept working all the time. If shut down, a blast furnace takes some time to get back in working order again. It must be reheated to the high temperature at which the iron melts.

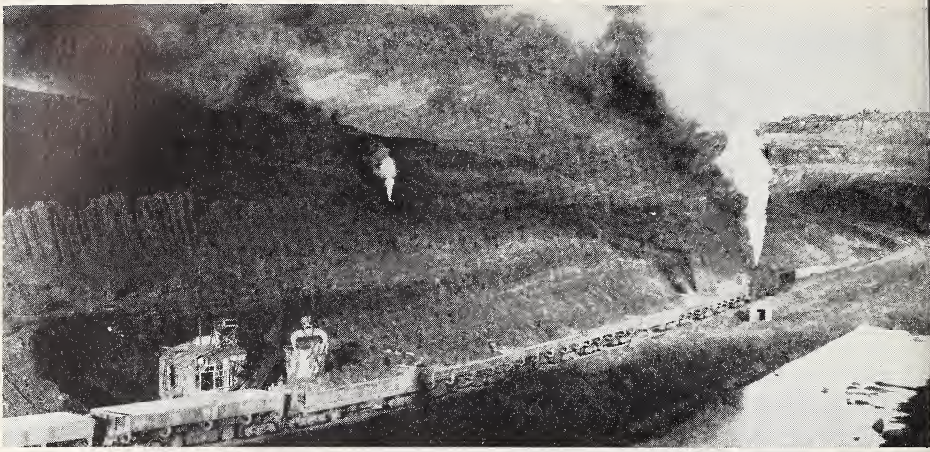
Pig iron may be melted and poured into molds of different shapes to form automobile engine blocks, stoves, and bases for heavy machinery. Such iron, called cast iron, will not stand bending or heavy shocks or blows. It breaks under such treatment.

Steel, the Backbone of Industry

No other man-made material is so strong or so tough as the different kinds of steel made today. Steel may be made into many shapes and sizes, with the strength of cast iron but without its brittleness. Steel may be rolled, red-hot, and formed into steel rails for railroads. It may also be

165 When a current of electricity is passed through the melted aluminum ore, the aluminum separates from the ore and collects on the bottom of the electric cell.





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166 Notice the huge shovel that strips iron ore from the surface of this mine to fill the ore cars of a long train. This mine is in the Mesabi Range in Minnesota. Why is iron ore so important to industry?

rolled into strips for making tin cans. It may be pulled out into wires. It may be made into armor plates for battleships. From steel come the tools of industry, engines for factories, airplanes, automobiles, and trucks. Whether it is in a watch spring, pen point, or locomotive, steel plays its part in your everyday life.

What Is Steel?

The first step in making steel is to control the impurities in pig iron. Pig iron has in it a number of elements, such as silicon (SIL-ih-kon), phosphorus (FOSS-for-us), sulfur, and particularly carbon. These impurities are found in cast iron. To make steel, these elements are largely burned out of the iron. In this way the amount of carbon is lowered from about 4% to less than 1% (Fig. 167). Ordinary steel is really iron with just enough carbon, manganese, silicon, and a few other elements to make it tough. On the other hand, special steels are made that have certain properties. These steels can stand up under great heat, cold, rusting, and strain. They are made by adding exact amounts of one or more metals to molten steel. Thousands of types of steels, called

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167 Into the large pot at the left white-hot molten steel is flowing from a furnace where pig iron has been melted. Impurities, which float to the top, are running out of the spout into the pot at the right.

alloy (AL-oi) steels, are made by adding different metals to iron. An alloy, therefore, is made up of two or more metals melted together.

Alloys — Man-Made Metals

In general, alloys are different from the metals of which they are made. For instance, often they are harder and stronger. Today we would find it very hard — if not impossible — to have many comforts of modern life without the use of alloys.

Different Alloys

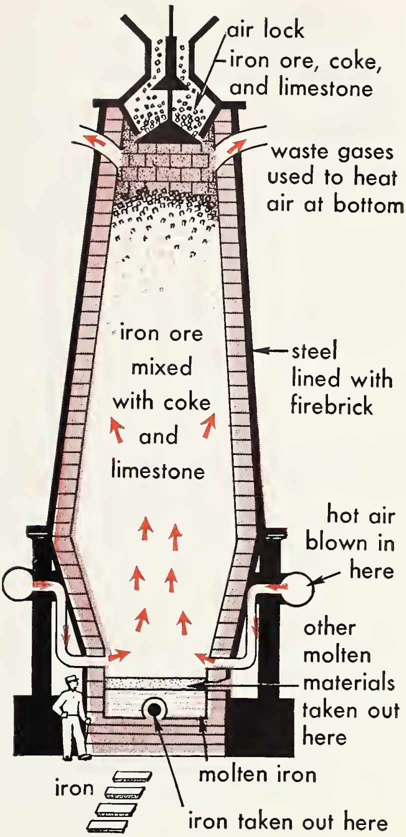
As we stated earlier, there are many different kinds of alloys. Steel alloys are those in which different metals are dissolved in steel. When about 4% of nickel is added to steel, the alloy is tough and withstands rusting. Gun barrels and armor plate, as well as bridge girders, are made of nickel-steel alloy.

Manganese in steel makes an alloy that is hard and tough enough to withstand blows. This alloy is used in railroad switches, office safes, and heavy road machinery. Silicon in steel makes an acid-proof metal used in making waste pipes for chemical plants. Stainless steel is an alloy made by adding nickel and chromium to steel. It is used in sink tops, cutlery, and wherever rustproof steel is needed.

Alloys are made of other metals. Perhaps the oldest alloy is bronze, made of copper and tin. It can be shaped and does not rust easily. It is used in coins, ship fittings, statuary, and ornaments. Other common alloys, their uses, and what they are made of are found in Table 11.

The last two alloys in the table, Duralumin (dyoo-RAL-yuh-min) and

BLAST FURNACE



168 In the blast furnace very hot air causes the coke to burn, which melts the materials — iron ore and limestone — to make iron. Molten iron is tapped from the bottom of the furnace and is cast into bars called "pigs." The lighter molten material with its impurities is drawn off above the molten iron.

Dowmetal, are very strong and light. Without these the modern airplane could not be built. Likewise, other alloys of aluminum and magnesium have been made to meet the growing demand for safer and faster airplanes. Think of household items in which strong, light metals would be useful.

TABLE 11 Common Alloys

Common Name	Alloy of	Use
Brass	Copper, zinc	Water pipes, hardware
Babbitt metal	Copper, antimony,* tin	Engine bearings
Type metal	Lead, antimony, tin	Type for printing
German silver	Copper, zinc, nickel	Tableware
Wood's metal	Bismuth, lead, tin, cadmium	Low-melting alloy plugs in fire doors, oil storage tank valves and automatic fire extinguishers in factories, public buildings, schools
Duralumin	Aluminum, copper	Airplane coverings and framework
Dowmetal	Magnesium, aluminum	Airplane parts, forgings, wings, ladders

* (AN-tih-moh-nee).

COAL AND OIL — OLD FUELS

You have learned that steel is the backbone of industry. But in order to make steel, you must have iron. In order to make iron, you must have coke. In order to make coke, you must have coal. It is like the lines from the old jingle:

For want of a nail the shoe was lost,
For want of a shoe the horse was lost,
For want of a horse the rider was lost,
For want of a rider the battle was lost.

If you apply this idea to coal, you will find coal the nail upon which modern civilization depends.

Coal — A Basic Fuel

Without coal most factories would shut down, and many cities and towns would be without gas, electricity, and power. Moreover, we would soon be without many medicines, dyes, and other products that are made from coal.

Coal is found in many parts of the world from North to South Pole. Early in the earth's history plants grew thickly in the warm moist climate. As the dead plants fell, they were gradually buried. Slowly they were pressed down and heated within the earth. Layer after layer of these plants became pressed together by changes in the earth's crust. Gradually they changed into coal. How do we know that there was once tropical growth near the North and South Poles? Simply because coal has been found in those regions.

Different Kinds of Coal

The most useful coal for industry is soft coal.[1] To see why, take a test tube and fill it half-full of small pieces of soft coal. Fit a one-hole stopper with a delivery tube to this test tube (Fig. 169). Pass the end of the delivery tube through one of the holes in a two-hole rubber stopper. In the other hole place a piece of glass tubing, one end of which has been drawn out to a narrow opening. Fit this stopper into another test tube.

Heat the test tube containing the soft coal. After two minutes hold a lighted match near the drawn-out

[1] Soft coal is called *bituminous* (bih-TYOO-min-us) coal.

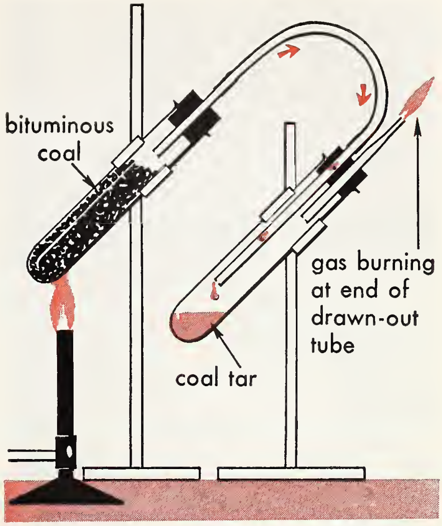
end of the glass tubing. Why does it burst into flame? Keep on heating the tube until the flame goes out. Examine the yellowish-brown material in the bottom of the second test tube. Take your apparatus apart and examine the material left from the coal in the first test tube. What does it look like?

Here is what you have done. You have, on a small scale, entered the gas business. You took soft coal and heated it without any air present. (You drove out the air in the test tube by heating.) The soft coal then gave out a gas, like the gas you burn in a gas stove. That gas you lighted with a match.

The material at the bottom of the first tube is coke, which is used for heating homes and for making steel. The liquid in the bottom of the second test tube is coal tar. From coal tar are made many dyes, drugs, plastics, perfumes, and food flavors.

Soft coal is very useful, isn't it? But that is not the whole story. Heat energy from soft coal runs engines and the machines in factories, and its energy can be turned into electricity. In most sections of the country, you will find soft coal also being used to heat public buildings and many homes.

Another kind of coal, used mainly for heating homes, is hard coal.[1] Hard coal burns with less ash and soot than does soft coal. Many homeowners like it for this reason. Another type of coal is peat, which is burned in many sections of the world where there is not much soft or hard coal. The United States is lucky to have large deposits of the best grades of coal, even though



169 Soft coal when heated produces cooking (illuminating) gas and valuable materials such as coal tar and coke.

it uses 500 million tons a year. Mining engineers think that we have enough coal to last more than 3,000 years. In 1953 a very hard type of coal was discovered under rock layers in Michigan. Perhaps you will read about this and other discoveries of coal in your newspapers.

Oil — The Lifeblood of the Nation

Man's ability to travel at modern speeds depends largely upon oil.[1] About three-fourths of the world's oil is used for transportation — to give power to automobiles, steamships, airplanes, railroad trains, trucks, and buses, and to keep their moving parts oiled. Oil is also used in countless machines that help man do his daily work faster and cheaper.

[1] Hard coal is called *anthracite* (AN-thruh-syt) coal.

[1] Oil, as used here, means crude oil, from which we get gasoline, kerosene, automobile oil, and oil for heating.

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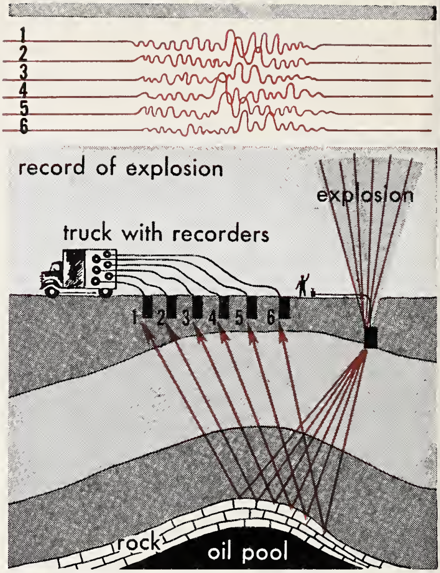


170 How scientists use echoes from exploding dynamite to detect the presence of an oil dome far underneath the earth's surface. The explosion sends sound waves downward. The rock formation reflects them upward to the surface. The pattern of the returning waves on the record of explosion shows where the dome is located.

One-fourth of the world's oil is used for making kerosene for lighting, for heating homes, for making asphalt, rubber, wax, Vaseline, antifreeze, insect sprays, linoleum, medicines, plastics, and countless other items. Do you wonder that oil is called the lifeblood of the nation?

Searching for Oil

To most people there was always something strange about the way oil was buried far down in the earth's crust. Some men claimed they could find this oil with a forked stick. They carried the forked stick before them as they walked over an area being studied. Whenever the stick turned point down toward the ground, they claimed it pointed to a pool of oil. Others said they could smell oil. Still others said oil acted on them like a magnet so that they left tracks twice as deep over land covering a pool of oil. All these ways of finding oil, of course, were based on guesswork, not on scientific knowledge.

Today geologists have worked out a surer way of finding oil. They dynamite over an area where they expect to find oil (Fig. 170). A record is made of echoes coming back from rock layers far below the earth's surface. The shape of the rock layers can be drawn from these records. When the echoes show a mound or dome of rock under which there is likely to be oil, the part of the dome closest to the surface is then found and a well is drilled. A dome of rock is formed by a wrinkling of the earth's

surface (Fig. 170). In oil-bearing country this dome is usually made up of hard rock. Under that rock is a large mass of porous rock or sand filled with oil and gas, or gas alone.

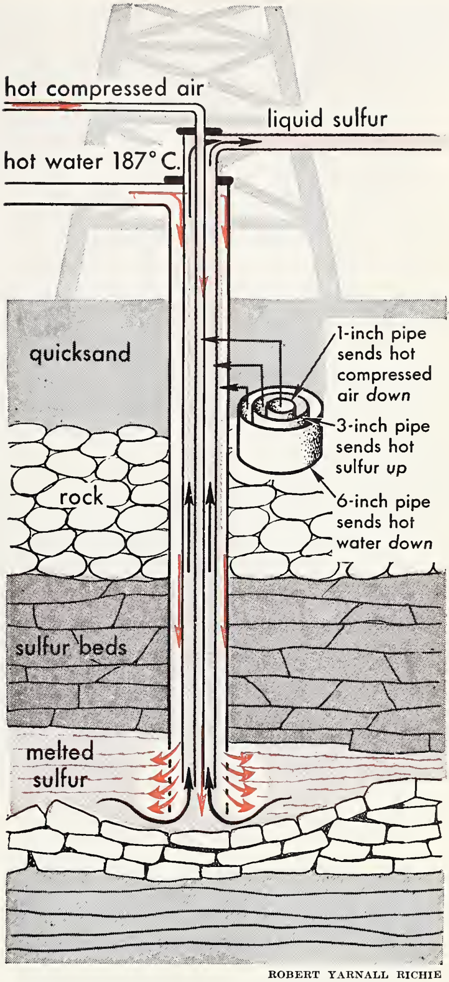
When a well is drilled through the dome, several things may happen. First, a pocket of natural gas wet with gasoline may be found. After taking the impurities out of this gas, the gas is piped to cities and towns. There it may be used for heating and cooking. Second, the pressure of gas or water on the oil under the dome may push the oil up the pipe with great force. To prevent loss of valuable oil from each newly drilled hole, the hole is capped so that the oil can be piped out when needed. Third, the oil may rise only part way up the pipe and may have to be pumped the rest of the way. Fourth — and this happens many times — the well may be dry and yield nothing.

IMPORTANT MINERALS

Sometimes the search for oil has led to the discovery of other important materials.

Sulfur — A Measure of Wealth

Would you have been as disappointed as these men were? Over 60 years ago, four men drilled for oil in Louisiana, near the Gulf of Mexico. Instead of oil they discovered sulfur. It was 500 feet below the surface. It could not be mined like coal because drill samples showed water and sand above the sulfur. The men then gave up in disgust. Herman Frasch (FRAHSH) heard about these beds of sulfur in 1891. He decided that, if he could not go down to the sulfur, he



ROBERT YARNALL RICHIE

171 Herman Frasch invented this process of getting pure sulfur from the earth's storehouse. Superheated water goes down the outside (6-inch) pipe and melts the sulfur. Hot, compressed air goes down the central (1-inch) pipe and forces the liquid, pure sulfur, up the middle (3-inch) pipe.

would make the sulfur come up to him. Look closely at Fig. 171. Don't you think that Herman Frasch had a good idea? Before Frasch developed this idea, the United States had to

get sulfur from foreign countries. Today all sulfur in this country comes from these wells.

Sulfur is a hard yellow element at room temperature. But it may be melted easily. Sulfur is very important to industry. In fact, it is said that the wealth of a nation can be measured by the amount of sulfur it uses. The United States uses over 5 million tons each year in making sulfuric acid, matches, paper, plastics, sprays against insects and molds, ointments, and in treating rubber.

Salt — A Basic Mineral

"That will cost you half a pound of salt!" You may not have heard this expression, but you would have heard it had you lived in Kentucky in Daniel Boone's time — or even today if you lived in Ethiopia or Tibet. Have you heard of people being called "the salt of the earth"? Or the saying, "You are worth your salt"? These sayings come from the fact that salt is such an important mineral. Two thousand years ago salt was so valuable that Roman soldiers were paid with it. In fact, our word "salary" comes from the Latin word *salarium*, which means a Roman soldier's pay in salt. Even today some governments tax salt and its uses, and, where salt is scarce, some people use it for money.

Salt (sodium chloride) is a food necessary to life. It is also used in making other necessary products for the home. For example, baking soda and washing soda are made from salt. Chlorine, used to purify the water supplies of many cities and towns, is also made from salt. The chemical industry uses 10 million tons of salt each year in making these and hundreds of other products.

Evaporation of water from ancient seas left large beds of salt now mined in the United States. For example, millions of years ago, there was a deep hollow in what is now the lower part of Michigan. Time after time this hollow was filled by ocean water that evaporated and left salt behind. In fact, over a thousand feet or more beneath the city of Detroit this salt is being mined today.

Many beds of salt below the earth's surface are mined by sinking shafts and digging tunnels. Most, however, are mined like sulfur. Water is sent down to the bed in one pipe to dissolve the salt, which is then pumped up through another pipe. The water is evaporated, and the salt is left behind. Near Watkins Glen, N.Y., salt is mined this way. However, in many parts of the world a great deal of impure salt is obtained from salt lakes and the ocean simply by evaporating the water.

Limestone and Cement

Without limestone no large modern building could be built. Limestone is an important part of cement, and cement is used in making foundations, floors, and supports for modern buildings. To make cement, limestone is mixed with clay. This mixture is then heated and ground to a fine powder. It is used to make concrete.

Concrete is made by mixing one part of cement with two to four parts of sand and gravel or crushed rock. Water is added, and the mixture hardens into concrete. Concrete may be reinforced, that is, made stronger. When it is used for roads, walls, and floors of buildings or for dams, con-

ROBERT YARNALL RICHIE

172 Sulfur from a Frasch well in Texas is being sprayed into a bin that will eventually form a huge block of sulfur like the one in the background.

crete is reinforced by pouring it around steel rods. Reinforced concrete is hundreds of times stronger than ordinary concrete. A simple experiment will show you why.

Mix enough concrete (one part of cement with four parts of sand) and enough water to make a moist mixture to fill two shallow boxes like the wooden flats (boxes) used by florists. Push a layer of chicken wire or window screening into the soft mixture in one box when it is half full. Fill the rest of the box with the mixture. Now fill the second box with the mixture, too, but leave out the screen or wire. After the concrete has hardened, remove the slab of concrete from each box. Place each slab so that its ends are on some bricks or pieces of wood. Step upon the middle of each slab. What do you find about the strength of the reinforced concrete?

Over 175 million barrels of cement are used yearly in the United States to make concrete for buildings, dams, bridges, and roads. From this you

can get a good idea of the amount of concrete that is made.

Clay and Sand

For centuries men have known how to make bricks, tile, and earthenware vessels from clay. Have you ever heard of the potter's wheel? As it turns, a skillful potter can make beautiful vases by molding the wet clay. Baked in an oven, painted, or treated with a colored glaze, these vessels are always in demand today. The plate you eat from, the cups and saucers and other dishes you use probably are made from pressed clay formed on something like the potter's wheel.

The glasses you drink from, the dishes used in baking, the windowpanes you see through, the glass blocks used in building are made by different methods. But sand is the common material used in each method. Ordinary window glass is made by melting sand with calcium carbonate and sodium carbonate. Liquid glass is first blown out into circular, uneven sheets. These sheets are flattened and cooled slowly. Then the sheets are cut into the needed sizes.

Plate glass is made by rolling molten glass into a sheet upon a metal table. The sheet is then cooled slowly and ground and polished. Plate glass does not have the uneven, wavy surface of window glass. Carefully ground and polished glass also makes the lenses for eyeglasses, cameras, and giant telescopes, like the one at Mount Palomar you read about in Unit 3.

Shatterproof glass is made by joining two pieces of plate glass together with a filmlike sheet of plastic glued between them.[1] If a shatterproof automobile windshield is hit, the plastic keeps the glass from flying and cutting passengers (Fig.173).

Glass is one of the most useful substances in the world. Millions of bottles are made each year by pressing hot glass into molds. The chemist depends upon glassware for his beakers and other bottles. Spun into fine threads, glass is used as glass wool for insulating homes. Even finer threads of glass are colored and woven into waterproof, fireproof, nonfading cloth. Glass has indeed become a worldwide servant.

SAVING OUR MINERALS

The United States is the wealthiest nation in the world, partly because its land has many of the minerals you have been reading about. It was once thought that there were enough of these minerals to last the United States forever, but World War II changed that idea. During that war the United States used up 5 billion tons of its richest minerals and over 8 billion barrels of oil. Today our mercury is 97% gone; silver and lead, 83% gone; copper, zinc, and oil, 60% gone; and almost all our high-grade iron ore is used up.

If we keep using up our minerals without planning, we will become a have-not nation instead of a have nation; we will be poor instead of rich. Is it too late to start saving now? Not at all, as you shall see.

Conserving Coal

Scientists think our coal resources will last at least 3,000 years. This

[1] The word *plastic* is used to describe materials such as cellophane. Have you a raincoat made of filmlike plastic?

does not mean that we may mine and use coal wastefully. It costs a good deal of money to mine coal, and, as the coal near the earth's surface is used up, the cost of mining will increase. Everyone who uses coal or things made from coal will then have to spend more for coal.

The people of Pennsylvania knew these facts and in 1939 acted to mine their great deposits of hard coal wisely. In that year they passed the Pennsylvania Commerce Act. This act allows miners and mineowners along with the State Secretary of Mines to plan the mining of hard coal. Each Monday, representatives of the coal miners, the mineowners, and the Commonwealth of Pennsylvania meet to decide how much coal is to be mined that week. With this kind of action, it is possible for the mineowners to plan how much they will mine. As a result, waste is kept very low, and the coal of Pennsylvania is mined with care so that the coal beds will last longer.

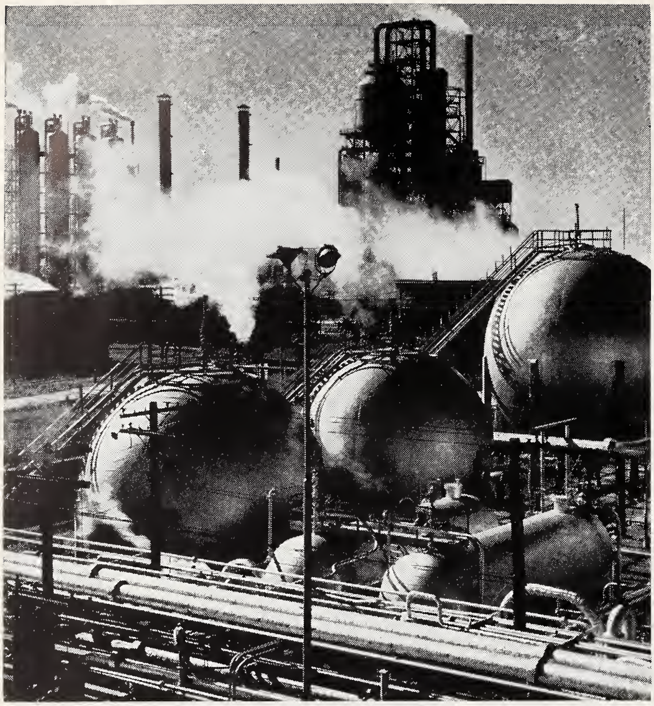
For heating homes, running factories, and making electricity, coal ranks first as a fuel. In the past, over one-third of the heat from coal has gone up the chimneys, doing no one any good. Better methods of burning coal have been invented, so that today this loss is now cut in half. Many homes have an invention (known as an automatic stoker) for burning coal more completely in the furnace. Industrial plants have found ways to use one pound of coal to do the work of three. Also we will use less coal for heating and cooking by using electricity made by water power. These and other methods about which you will read later are the modern ways of using our coal resources wisely.

PITTSBURGH PLATE GLASS CO.

173 This shows that glass 2½ inches thick can be made strong enough to stop rifle bullets. "30.06" is a factory mark.

What Are We Doing to Conserve Oil?

We have in this country over 60 million automobiles and 15 million trucks, millions of oil burners in homes and in industries, countless airplanes, tractors, and bulldozers. All these use gasoline and oil. Thousands of oil products, such as asphalt for roads, synthetic rubber, waxes,



STANDARD OIL CO. (N.J.)

174 This oil refinery gets the oil it uses by underground pipelines from oil wells.

dyes, and drugs are needed for everyday use. Moreover, one-third of the nation's yearly supply of oil is used each year by the armed forces. Add these all up, and you have a staggering total of over 100 billion gallons — almost 2 billion barrels used each year. Can we keep on at this rate without coming to the end of our oil supply? Let us look at the facts.

Today our known oil reserves are 22 billion barrels. At our present rate, we shall use all our known supply from wells by 1968. But these reserves are not our only oil resources. In this country we have over 1½ million square miles of land that might produce oil. Only one-half of this area has been searched for oil. Geologists tell us we may expect to find in the future as much oil as we have produced in the past. That would mean another 50 billion barrels. Added to our known resources, that would give us enough oil for the next 35 or 40 years.

Recently scientists have reached the oil under the ocean shores where the tide rises and falls. These areas are called tidelands. They are a rich source of oil, called tideland oil. You will hear a great deal about tideland oil in the future.

Today, many states have oil conservation laws. The aim of these laws is to draw from the earth only as much oil as is needed. New wells are still being sunk and new fields are still being explored for the future.

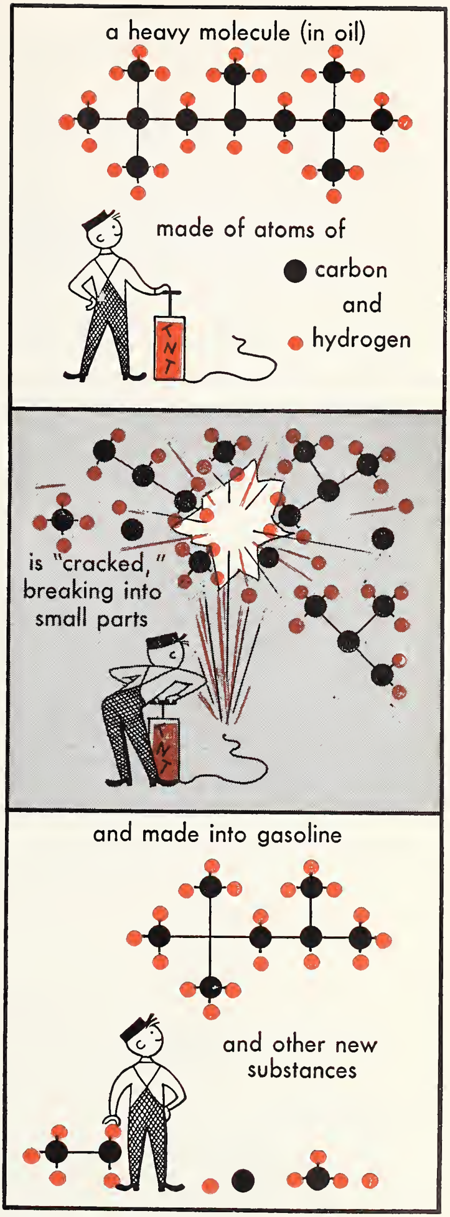
The day of the wasted oil well is past. Gas or water pumped into old wells brings all but a small part of the

underground oil pool to the surface. Formerly, three-fourths of the oil was left in the ground. Furthermore, both oil and gas wells are used. Gas and oil are carried thousands of miles by underground pipelines.

Greater care is also being used in making gasoline from oil. Much of today's gasoline is made from a process known as "cracking." In cracking, the oils are boiled at a high temperature and heated under great pressure. This causes the heavier oil to break down into the lighter gasoline (Fig. 175). New methods of cracking oil are giving the nation more gasoline from each barrel of oil than it got before. In these ways we are trying to conserve what oil we now have.

Conserving Metals

During World War II we learned from metal shortages that our resources of ores are limited. Today, it may not be possible to find new supplies of rich iron, copper, lead, zinc, gold, or other ores. It is a question of conserving what we have. We need still better methods of using the poorer ores that remain untouched. Our good iron ore in the Mesabi Range in northern Minnesota, from 50 to 60% pure iron, may last for 30 years or so. It will not last as long as that if we use it up at the same rate as we have since the beginning of World War II. During the war nearly 90 million tons of ore were loaded and shipped from the Duluth-Superior harbor each year. The average before the war was about half that much. We still have in Minnesota a great supply of lower-grade iron ore, about 30 to 35% pure iron. Science and industry are now hard at work



175 Molecules of heavy oils from oil wells are "cracked," or heated under great pressure, to make one-quarter of the gasoline used in the United States today.

to find a cheap way of getting the iron from this low-grade ore. Meanwhile great beds of iron ore have been discovered at Steep Rock, Canada, and in northern Labrador. They are now being worked.

Our copper, zinc, lead, and other ores are in nearly the same condition; that is, the richer sources are almost gone and we are seeking ways and means of using the poorer ores. We do not have enough of certain other metals, such as tin, chromium, and tungsten. We have to buy them from other countries.

You have already read about rusting of iron and how paint protects the iron. Coating with zinc is another way of protecting iron. This process is called *galvanizing* (GAL-vuh-nyz-ing). The zinc protects the iron for a long period of time. Still another way is to coat iron with tin, as in the process of making tin cans. Only when the thin coating of tin is removed by wear or scratching does the can rust. Enameling and plating are other methods of protecting metals which rust. Silverplating may protect some of your tableware. If you have something made of iron or steel which you want to store, a coating of oil or grease will help keep it from rusting.

It would be impossible to list all the materials we need to conserve. Those we have mentioned are only a few examples. As you go on in your study of science, you will learn more about how we are conserving our other minerals.

Then, too, scientists are discovering new products to replace those found in the earth. Many of these new products are better than materials found in the natural state. In "Going Further" you can investigate some of the new materials scientists have made.

No matter where you go or where you look, you will see man inventing new ways of doing things. He is using his brain to conserve the storehouse of minerals for all the world. He is beginning to mine the earth's crust wisely and intelligently. But he does more. He takes materials from the earth's storehouse and improves on them. By so doing, he adds to the materials he can use to improve his ways of living. Here is another example of "science for better living."

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct word after its meaning. DO NOT MARK THIS BOOK.

aluminum	alloy	galvanizing
blast furnace	soft coal	conservation
cast iron	hard coal	
steel	sulfur	

1. a metal that is used as a base for heavy machinery
2. coating iron with zinc
3. a coal from which we get coal tar
4. a light, strong metal used in airplanes and in the home
5. a coal that leaves little ash when burned
6. a furnace used to make iron from iron ore
7. a different kind of metal made by melting two or more different metals together
8. a yellow element used in making sulfuric acid and paper
9. a metal with the strength of cast iron, but without its brittleness
10. wise and intelligent use of resources

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. Protecting iron with a coating of zinc is known as . . . .
2. When the right amounts of carbon, manganese, and silicon are added to iron, . . . is made.
3. Coke is made by heating . . . .
4. Pig iron is melted in molds to make . . . .
5. When two or more metals are melted together, an . . . is made.
6. Because it leaves little ash after burning, . . . is used by many people for heating homes.
7. . . . is made by mixing one part of cement with two to four parts of coarse sand and gravel, and then adding water.
8. When limestone and clay are heated and ground to a fine powder, . . . is made.
9. Pig iron is made in the . . . .
10. Charles Hall discovered a cheap way to make . . . .
11. The wealth of a nation can be judged in part by the amount of . . . it uses.

GOING FURTHER

In the Laboratory

1. *Examining metals.* Get from a plumber or a hardware store some small pieces of lead, tin, aluminum, and copper wire and a piece of magnesium ribbon (from your school laboratory). Note the color of each metal. Are the colors different? Try scratching each metal with the point of a knife. Which metal is the softest? Hold a piece of each metal in the flame of a Bunsen burner. (Use a pair of forceps.) Which metal melts the quickest? Which metal would be best for a teakettle — lead, aluminum, or magnesium?

2. *Making an alloy.* Place in a heavy porcelain dish a piece of thin sheet lead about 1 inch square, and about the same amount of tin. Set the dish in a small ring of a ring stand and heat with a Bunsen burner. As soon as the metals have melted, stir the liquid metal for an instant with the handle of a spoon or the end of a file. Now join two clean copper

wires by twisting the ends together, and dip the twisted wires into the liquid metal. Remove the wires and let them cool. Can you untwist the copper wires?

You have made solder (SOD-er), an alloy of lead and tin, by melting these two metals together. When you dipped the twisted copper wires into the molten solder and let the wires cool, the solder fastened the two wires tightly together. Wires are soldered in electric wiring systems in homes and in radio and television sets.

3. *Preventing rust.* Get a tenpenny galvanized nail and two tenpenny ordinary nails from a hardware store. Sandpaper the surface of the two ordinary nails. Fill three glasses with water. Place the galvanized nail in one glass and one of the ordinary nails in the second glass. Rub a little light oil on the surface of the other nail and place it in the third glass of water. Examine the nails each day for five days. Which nail rusts? Remove the galvanized nail and the oil-coated nail and wash them in soapy water. Replace the nails in their separate glasses of water. Examine again after five days. Is galvanizing a better protection for iron than oil is?

4. *Oiling metals.* Take two pennies and rub them together. Now place a drop of oil between the pennies and rub them together. Do you notice any difference? Where one metal surface moves over another, the surfaces must be greased or oiled. If it were not for oil, modern machinery could not work.

5. *Making mortar.* Fill a large beaker or bucket one-quarter full of quicklime. Add enough water to cover the lime by half an inch. Is there any evidence of heat or of chemical action? Now stir in (with a spoon) enough sand and water to make a thick paste. Take two wet house bricks and spread a layer of this mixture on the surface of one. Place the other brick on this surface and with a stick wipe from the joint any extra mortar that is squeezed out. Let it stand 48 hours. Are the two bricks joined together? Is the mixture between the bricks hard?

You have made a mixture, called mortar, by adding water and sand to quicklime. Mortar hardens in air, and then it binds bricks together. How does a mason use mortar to build chimneys and brick houses?

Put on Your Thinking Cap

1. A party of geologists found that echoes of an explosion they had set off showed a domelike formation of underground rock. What possibilities does this suggest to you?

2. To be an industrial nation today, a nation must have rich deposits of both iron ore and coal. Explain.

3. Why is it necessary to save coal if we have a good supply?

4. In what ways can you save fuel in your own home?

5. How is the oil industry preparing to meet any shortage of oil?

Adding to Your Library

Your reading for this chapter is divided into two groups: career pamphlets from the sources listed below, and books.

BOOKS

1. *Deep Treasure* by Elizabeth Olds, Houghton, 1958. A story of oil.

2. *Aluminum the Miracle Metal* by C. B. Colby, Coward, 1958. This book tells you how it happened, how it is made, and how it helps make "modern living" possible.

3. *Vein of Iron: The Pickands Mather Story* by Walter Havighurst, World, 1958.

4. *Mining Round the World* by June Metcalfe, Walck, New York, 1956. A collection of stories about minerals, mines, and men.

5. *Diamond* by Emily Hahn, Doubleday, 1956. A spectacular story of earth's rarest treasure and man's greatest greed.

PAMPHLETS

6. *Chemicals,* Merrill Lynch, Pierce, Fenner, and Smith, New York, 1958.

This interesting pamphlet tells you about chemical companies and the products they make. It is meant for investors, but you will enjoy reading about chemicals.

Here are some career pamphlets you may want to get:

7. *There's a Place for You in the Oil Industry*, American Petroleum Institute, New York, 1957.

8. *Petroleum Exploration and Production Workers*, Occupational Briefs No. 195, Science Research Associates, Chicago, 1957.

9. *Technical and Teaching Careers in Geology*, Institute for Research, Chicago, 1956.

10. *Should You Go into the Mineral Industry?* by John W. Vanderwilt, New York Life Insurance Company, New York, 1956.

11. *Metal Mining Workers*, Occupational Briefs No. 194, Science Research Associates, Chicago, 1957.

12. *Iron and Steel Industry* by Tom Campbell, Bellman, Box 172, Cambridge, Mass., 1957.

13. *Plastics Industry Workers*, Occupational Briefs No. 125, Science Research Associates, Chicago, 1956.

14. *Rubber Industry Workers*, Occupational Briefs No. 129, Science Research Associates, Chicago, 1956.

A Bit of Research

Scientists have made many new materials as substitutes for or improvements on materials found on the earth. Make class reports on the following:

1. The advantages of artificial (synthetic) rubber over natural rubber. Include information on silicone rubber.

2. The history and uses of *plastics*. Be sure to study celluloid, bakelite (BAYK-uh-lyte), lucite, and cellophane.

3. How man-made fibers are being used in place of cotton, silk, and wool. Tell how the following are made and used: rayon, nylon, Lanital (LAN-ih-tawl), Orlon, and glass fibers.

4. How we may have any color (dye) today because of the work of chemists. Read the story of William Henry Perkin, who made the first laboratory dye (mauve) in 1856 when he was only 17 years of age.

5. Make a report on how soap is made, and some advantages and disadvantages of "soapless soaps," commonly called *detergents* (deh-TER-junts).

6. Are some of your clothes dry-cleaned? Find out what chemicals dry cleaners use, and report why such chemicals are better than ordinary soaps for some clothes. Your report should have in it the reason why flammable liquids (liquids which catch fire easily) are not used in dry-cleaning shops. Should they be used for dry-cleaning at home?

Careers for You

All the opportunities for positions in the *mining*, *coal*, *steel*, *oil*, and other *industries* cannot be listed here. Each industry needs trained people; in fact, most industries give further training for the jobs they select you to fill. For example, industry lists hundreds of opportunities for careers in oil. (Send for *Careers in Petroleum*, American Petroleum Institute, 50 West 50th St., New York City.) Men and women who take physical and biological sciences in college are frequently offered jobs even before graduation. Dr. Edward Cooper, in charge of a laboratory for research in plastics, said recently: "We are always in need of additional people with scientific background. Right now we could use seventy men and women to work on new research projects. We are now combing the universities for these people."

CHEMISTRY AS A hobby

How do you make a start in chemistry? Probably you are already a chemist without realizing it. At least, it is fairly certain that there is one chemist in your family — your mother. Every time she makes cookies or bakes a cake or biscuits, she is making something different from the materials she uses. That is what a chemist does. So if you have done any cooking, you have already made a start in chemistry.

Chemistry and You

Look around you — it makes no difference where you are. Either you see chemistry at work or you see what chemistry has had a part in making. If you are outdoors, each living thing you see, from an ant to the tallest tree, is a chemical workshop. Even you and the friend you may be studying with are chemical workshops in motion. You are making carbon dioxide, for instance, every time you breathe.

Chemistry has a part in making everything you wear and everything you use. It has had a part in making the dyes which color your clothes, the materials which clean them, and those which protect them against moths. It has tanned the leather in your shoes and it has made the stockings you wear. It has helped make the paper in this book and the ink that was used to print it. It has made the barrel of your fountain pen and mixed the graphite and clay in the lead of your pencil. Going further afield, chemistry has had a part in making every metal article you see, from a steel rail to an aluminum dishpan, every drug from aspirin to penicillin, every dye from mauve to Congo red, every plastic from cellophane to lucite. In truth, chemistry is one of the most useful of all sciences, and you cannot escape meeting chemistry or its products every day of your life.

Do You Need a Laboratory?

If you are really interested in making a hobby of chemistry, you will need some sort of laboratory. Do not be afraid of the word "laboratory." Your mother has one — her kitchen. You may have a workroom or shop, but do not think that you must have a separate room. Perhaps you can share her kitchen, or you may find a place in the basement where there is running water and a sink. Gas or electricity for heating purposes is not needed. You can use an alcohol lamp, if necessary.

As for equipment, here are the most important things you will need:

1. Two test tubes — at least one of Pyrex glass. The Pyrex glass test tube will withstand changes in heat. It should be used when you boil liquids. You can get test tubes from a drugstore or from a scientific supply company.

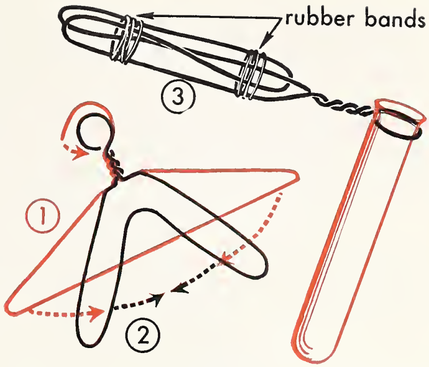
2. A test-tube holder. You can make it of wire. Use your own ideas. Use wire heavy enough to clasp the test tube and long enough to bend it into a loop to act as a handle. Or you can buy a test-tube holder from a scientific supply company.

3. Two beakers, or glasses from the kitchen.

4. Litmus paper, red and blue, from a drugstore. Litmus paper is used to test for the presence of acids and bases. Blue litmus paper turns red when moistened with an acid substance, such as vinegar. Red litmus paper turns blue when moistened with a base, such as washing soda.

5. An alcohol lamp to use when you need heat.

And that is all. Of course, as you learn to do more things with chemistry, you can get more test tubes, glass tubing, rubber tubing, flasks, a ring stand, clamp, and ring to support a flask, as well as scales to weigh out materials. You need only the materials mentioned above.



176 A wire coat hanger can be made into a useful test-tube holder. *Project:* With your parents' permission, why not begin to build up a small laboratory of your own? You can make many of the things you may need.

Testing Acid and Basic Substances

Of course, you know what acids are. Some, like strong hydrochloric acid or sulfuric acid, can eat away metals, shoes, and clothing. Others are weak, like the acid in vinegar, or diluted (a very small amount and in a large amount of water), like very dilute hydrochloric acid. Acids play an important part in your daily life, as in the digestion of food in your stomach.

Bases are substances which neutralize acids. They are strong in their own way. Some bases have the power to dissolve grease or wool. Materials used to clear out clogged sink drains are mainly made up of the base sodium hydroxide, which dissolves sludge and grease. Other materials, like soap, contain mild bases.

Now let us test some of the familiar substances around home. Take a lemon or a grapefruit. Cut it open. Draw a piece of blue litmus paper across the cut end. Blue litmus paper turns red in the presence of an acid. Is the fruit acid?

Test the liquid from a bottle of chlorine water used in bathrooms and kitchens. Use blue litmus. What happens?

There are a number of other substances in your home which you can test for acid reactions. How about vinegar? mayonnaise? French dressing? There are a number of foods that have acid reaction to litmus. Would

TABLE 12 Acids and Bases

ACIDS	
Strong	*Weak*
Hydrochloric acid	Acetic acid (in vinegar)
Sulfuric acid	Hypochlorous acid (sold in jugs as chlorine water)
Nitric acid	Carbonic acid, the acid in ginger ale
Phosphoric acid	Tartaric acid (in baking powder)
	Citric acid (in fruit juices)

BASES	
Strong	*Weak*
Potassium hydroxide	Calcium hydroxide (milk of lime)
Sodium hydroxide	Magnesium hydroxide (used in milk of magnesia)
Ammonium hydroxide (weak in household solution of ammonia)	

you refuse to drink lemonade, orange juice, or grapefruit juice because they are acid?

To test basic reactions you need red litmus paper. The red litmus turns blue if a base is present. Moisten a piece of red litmus paper and touch it to a piece of soap. What color does the litmus turn?

Your mother may use ammonia in cleaning or in washing. Is ammonia water basic? Test it by putting a drop of ammonia water on a piece of red litmus paper.

Test all soaps or soap powders in your home with red litmus paper. Do they have basic reactions?

Rub a little kitchen grease on a small piece of cloth. Moisten another piece of cloth with ammonia and rub the stain briskly. As you remember, bases dissolve grease. Does the stain disappear? There are other chemicals that cause stains to disappear, but most of them are used by dry-cleaning shops.

Neutralizing Acid and Basic Substances

Fill your Pyrex test tube half-full of water. Place in it a piece of laundry soap the size of a pea. Heat the test tube until the soap is dissolved. If you do not have an alcohol lamp or a Bunsen burner, shake the test tube vigorously. Pour half the liquid into a beaker or glass tumbler. This liquid now has the base found in the soap.

Fill your other test tube half-full of vinegar. Vinegar has mild acetic (uh-SEE-tik) acid in it. Add the vinegar slowly to the soap solution. Test with red and blue litmus. If too much acid is present, the blue litmus will turn red. If too much base is present, the red litmus will turn blue. If you are very careful and painstaking, you can get a complete neutralization where neither red nor blue litmus will change color.

Now use your knowledge of acids and bases to make some soap. In this experiment you will use lye (sodium hydroxide). (*Caution:* Do not let any lye get on your hands or clothes or anywhere on your skin or near your face or eyes.)

Place 1 teaspoon of lye in a small beaker and add 3 teaspoons of water. Stir slowly and carefully until all the lye is dissolved. Let the solution cool.

Put 6 teaspoons of lard or other cooking fat in a small beaker or evaporating dish and heat it on a hot

plate until the fat melts. Remove the beaker and slowly pour the lye solution into the fat, stirring the mixture as you do so. Next, add ½ teaspoon of household ammonia, and keep on stirring until the mixture is about as thick as whipped cream. Place the creamy mixture in a small cardboard box or mold to harden. Let your soap harden for at least two days. Then:

1. Does your soap make a lather like any other soap?
2. Is the soap you made in any way like the materials you used to make it?
3. Is the making of soap a chemical change?

Interested Now?

In this hobby section you have barely looked through the peephole of the door to chemistry. Only a few elementary experiments have been presented. You have not made such important substances as dyes or plastics. With further instruction from chemistry manuals, you can go ahead in these fields.

You can go from here into the reading list which follows. Here you will find a number of good books on chemistry. Start with one of the books below. As you learn more chemistry and become skillful in using its tools, you will go on with other books, high school as well as college texts. You will find a note with each reference below, describing the nature of the book.

After you have done some work in chemistry, you may decide to become a chemist. Further training in high school and college will test whether your decision is a good one. Whether it is or not, you will have fun and learn something about one of the important sciences in the world.

Reading for the Amateur Chemist

1. *Experiments in Chemistry* by Nelson F. Beeler and Franklyn M. Branley, Crowell, 1952. These experiments you can do with materials and equipment you can find easily. Set up a home laboratory.

2. *First Chemistry Book for Boys and Girls* by Alfred P. Morgan, Scribner, 1950. A book full of instructions for experiments you can do at home.

3. *Picture Book of Chemistry* by Jerome S. Meyer, Lothrop, 1950. Chemistry is working all the time in people and in everything and everywhere. Boys and girls enjoy this book.

4. *Fun with Chemistry* by Mae B. and Ira M. Freeman, Random, 1944. Invisible writing, soda water gas, crystals of sugar, burning steel, starch from potatoes — these are some of the experiments in this book.

5. *There's Adventure in Chemistry* by Julian May, Popular Mechanics, 1957. Randy Morrow, an average boy in his early teens, discovers the secrets of science with his dad.

6. *The Golden Picture Book of Science* by Rose Wyler, Simon and Schuster, 1957. Read about animals, plants, rocks, gravity, day and night, rain and snow, sky and ocean. It includes 45 activities.

7. *Your Wonderful World of Science* by Mae B. and Ira M. Freeman, Random, 1957. All about earth, sun, weather, rocks, air, water, heat, cold.

8. *Experiments in Science*, rev. enlarged edition by Nelson F. Beeler and F. M. Branley, Crowell, 1955. Here are forty-five experiments to do at home, as: shocks from pennies, flameproofing cloth, making clouds and snow.

9. *What Happened?* by Ida Scheib, McKay, New York, 1955. Here are the science stories behind the news. A tanker explodes on the high seas. What happened? Lights all over the neighborhood suddenly go out. Why?

10. *Mr. Wizard's Science Secrets* by Don Herbert, Popular Mechanics, 1952. You can perform hundreds of tricks with science after you read this book.

UNIT 6

Improving the World's Food Supply

You know that plants are the food factories of the world. They make the food that keeps all members of the animal kingdom, including you, alive. To make food they need more than plenty of sunlight, water, and air; they need the right chemicals, too. These they take up from the soil through their root hairs. The scientist above is studying the effect of chemicals on the growth of bean plants. Better food for plants means better crops and better food for you.

Scientists also breed plants and animals to improve the world's food supply. Larger ears of corn mean more food from the same land. As a result of careful breeding, cattle today yield more beef and more milk, hogs more bacon and hams, and chickens more eggs. This unit is about the work of scientists who have developed better seed and better feed to meet the problem of supplying adequate food for the increasing population of the world. What you can do about the problem is also part of this unit.

Your Science Inventory

How much do you already know about improving the world's food supply? Copy the following questions in your notebook and write down your best answers. Check your answers when you finish reading this unit.

1 These traits are inherited: (a) eye color, (b) likes and dislikes, (c) opinions, (d) handwriting.

2 The animals most troublesome to man are (a) beasts of prey, like lions and tigers, (b) giant water animals, like whales and sharks, (c) insects, (d) snakes.

3 Most of the material in a plant is built from (a) air and soil particles, (b) air and soil water, (c) soil particles, (d) soil and water.

4 In making food, green plants use a gas that (a) burns readily, (b) supports burning, (c) gives plants a green color, (d) turns limewater milky.

5 To design an experiment which would help me find out what the stomates of a leaf do, I would use (a) alcohol, (b) carbon paper, (c) Vaseline, (d) water.

6 Each root hair of a plant is composed of (a) only one cell, (b) two cells, (c) several cells, (d) many cells.

7 Humus chiefly consists of (a) clay and sand, (b) decayed plant material, (c) subsoil, (d) minerals.

8 Soil that is best for growing plants will contain these living things: (a) only bacteria and earthworms, (b) only bacteria and molds, (c) only earthworms, (d) all of these.

9 Erosion can be most easily prevented by planting (a) beans, (b) corn, (c) potatoes, (d) trees.

10 Bacteria that add nitrogen to the soil are found on the roots of (a) clover, (b) corn, (c) grass, (d) potatoes.

11 The plant that produces new plants by means of runners is the (a) carrot, (b) geranium, (c) rose, (d) strawberry.

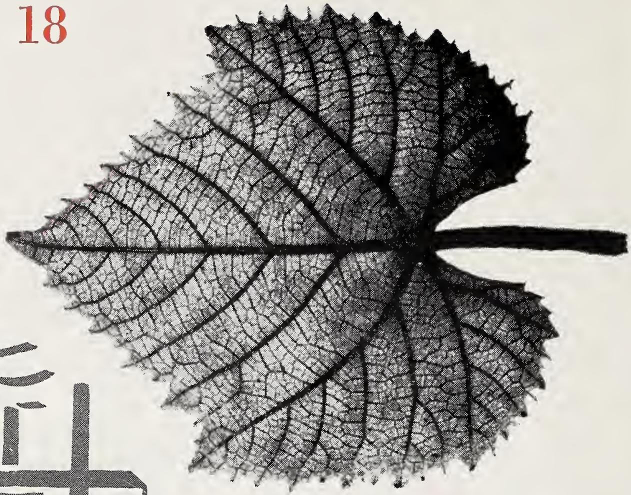
12 Grafting is most often used to obtain new (a) forest trees, (b) fruit trees, (c) garden flowers, (d) vegetables.

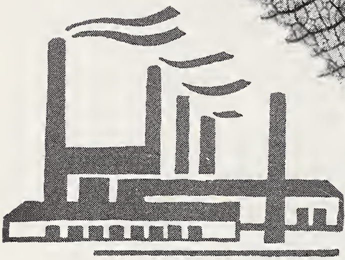
13 Adult animals that live on land but lay their eggs in water are (a) alligators and turtles, (b) frogs and toads, (c) lizards and crocodiles, (d) penguins.

14 Birds and mammals differ from all other animals because they (a) breathe air all their lives, (b) can learn, (c) have warm blood, (d) have a cerebrum.

15 The young stage that least resembles the adult stage is found in the life cycle of the (a) cricket, (b) grasshopper, (c) katydid, (d) moth.

CHAPTER 18





Food Factories of the World

Here is a green leaf. In it is the green "stuff" which enables it to make sugar, the basic foodstuff from which other foods are made. Green leaves are factories which make the food for all human and animal life.

WHAT was the Belgian scientist Helmont up to? First, he had taken a tub of soil and weighed it carefully. Then he had planted in it a young willow tree weighing about two pounds. In the year 1605, this was strange behavior!

The willow tree grew fast. It was watered regularly. After the willow had become quite large, Helmont carefully removed the tree from the tub. Then he weighed the tub with its soil.

He found that the tub and soil weighed about one pound less than when he had first planted the willow in it. But when he weighed the willow by itself, he found it had gained 70 pounds. Helmont decided that the gain in weight of the willow could not be due to the soil.

He thought, therefore, that the added weight and growth of the willow was due to water. At that time scientists knew very little about what water, air, and soil were made of, or how plants grow. Helmont's conclusions were not entirely correct be-

cause he did not have the facts we have today. The experiments in this chapter will give you some of these facts.

EXAMINING THE WORLD'S FOOD FACTORIES

During the past 100 years, scientists have learned many facts about plants. They now know a great deal about how plants grow and many of the materials they need for growth. Because of these facts, we are very sure that this statement is true: *We depend on green plants for our very lives.*

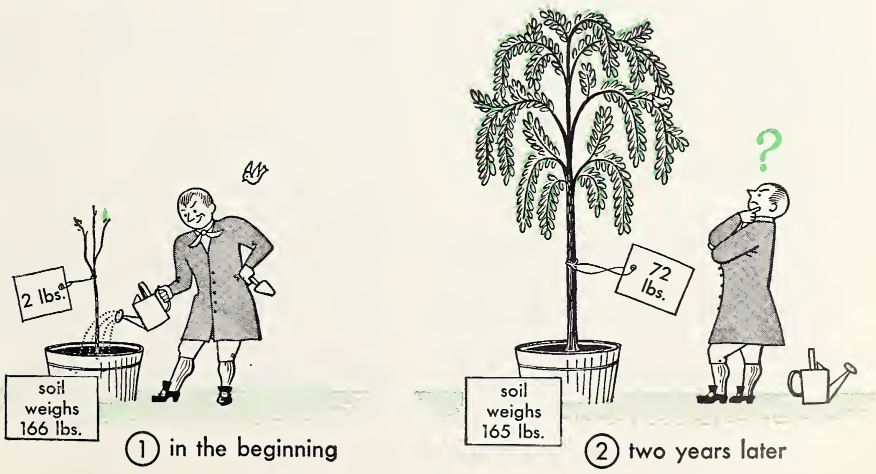
What are some of the facts that make us so sure that we could not live without green plants?

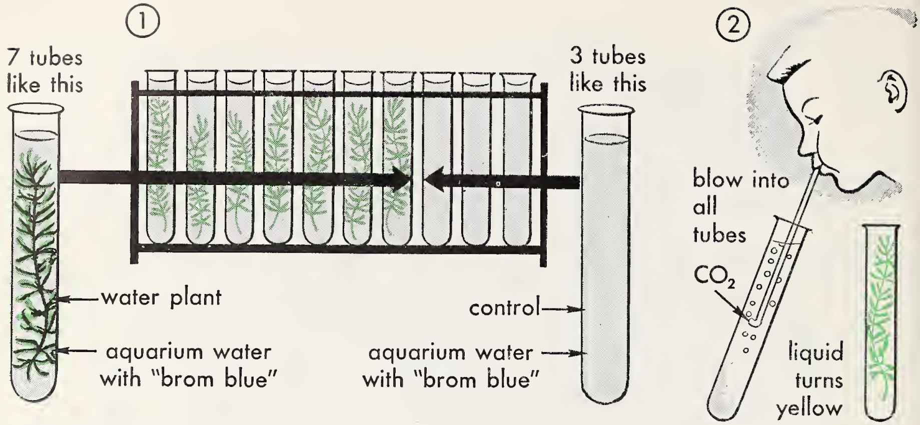
Sealing Up a Living Thing

In an eastern high school a group of students repeated Helmont's experiment, but instead of a willow they used a common water plant called *Elodea* (uh-LOH-dee-uh). They found that a sprig of their green water plant weighed 1.1 grams.[1] They placed the sprig in a large test tube filled half with *aquarium* (uh-KWAIR-ee-um) water and half with air. They sealed the tube by pulling it out in a hot flame and sealing the glass. The sealed tube weighed 57.5 grams. They placed the tube in indirect sunlight for three weeks. By then, the sprig had grown longer. They were surprised to find, however, that the sealed tube still weighed the same (57.5 grams). When they removed the sprig from the tube, they found that it had *gained* weight. It now weighed 1.7 grams (a gain of 0.6 of a gram). What had the plant used for growth? Since the plant was sealed in the test tube, it must have taken its food and materials for growth from the materials in the tube.

[1] 28.4 grams = 1 ounce
16 ounces = 1 pound
454 grams = 1 pound

177 Why did Van Helmont think his tree got its materials for growth from water? His experiment did not tell him that green plants used a gas, carbon dioxide, and the chemicals in the water.





178 *Project:* First read the text below which describes this experiment completely. Make up a 0.1% solution of the dye bromothymol blue. Add some of the dye to aquarium water in which water plants have been growing.

What was inside the tube? Your answer might be, "Just water and air." But here is where scientists have helped by gathering some important facts about water and air. These are the facts, as you know them from your work in Unit 5:

1. In water there are dissolved minerals and the gases oxygen and carbon dioxide.

2. Air is made up mainly of oxygen, nitrogen, carbon dioxide, and water vapor.

Which of these materials does the plant use for its growth? Perhaps we can plan an experiment to answer this question.

Green Plants and Carbon Dioxide

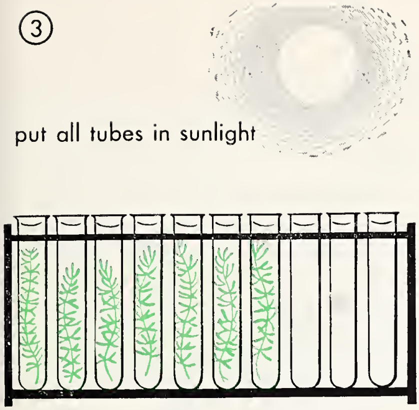
The first step in our plan might be to find out which of the materials in water and air are used by the plant. Then we would have a clue to help us with the next question: Which of these materials does the plant use for growth?

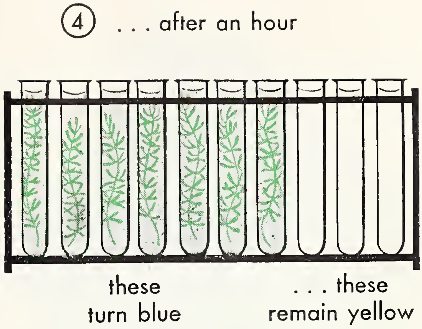
First, let us see if water plants use carbon dioxide. A certain blue dye (brom blue [1]) will tell us whether carbon dioxide is present. This blue dye is right for our first experiment for two reasons. First, water plants can live in it. Second, when carbon dioxide is added, the *blue* dye turns *yellow*.

Now for the experiment. Get ten large test tubes. Into seven of the tubes put sprigs of green water plants (Elodea, if you can get it), aquarium water, and some of the blue dye. The other three tubes will be the controls for the experiment. Into these three tubes put aquarium water and blue dye but no plants. Then blow into each of the ten tubes, using a straw. In a few seconds the carbon dioxide in your breath will turn the blue dye yellow.

Now put all the tubes in the sunlight. In about an hour the water in the tubes with plants in them will

[1] We will call it brom blue here, to make it easier to remember. Actually, the dye is called bromothymol (broh-moh-THYE-mohl) blue.





Do the experiment shown above several times with a different plant each time. Now repeat the experiment, but put half the tubes in the dark. What are your results?

turn blue again (Fig. 178). This shows that the carbon dioxide has disappeared. Where has it gone? Into the air or into the plants?

The three tubes without plants tell us the answer. Since the aquarium water in these tubes is still yellow, carbon dioxide must still be in the water. Therefore, in the other seven tubes, the plants must have taken in, or absorbed, the carbon dioxide.

Our first conclusion, then, based on these experiments and many others done on plants, is this: *Green plants take in carbon dioxide.*

Green Plants, Carbon Dioxide, and Light

Notice we suggested that the tubes be put in sunlight. What would happen if we put them in the dark? Let us repeat the experiment.

Into each of seven test tubes put a green plant with water and some of the blue dye. Do the same for three other tubes, but do not put in a plant. Then again blow through a straw into all the tubes. As soon as the carbon dioxide in your breath has turned the liquid yellow, put all the tubes into a dark place.

After one hour in the dark, the water will still be yellow. This shows that the carbon dioxide has not been absorbed by the plants. Even after leaving the tubes in the dark for 24 hours, we will find that the water is still yellow. However, when we bring them out into the light again for an hour or so, the yellow color in the seven tubes with plants in them will change back to blue. The three control tubes are still yellow. This shows that the green plants *in the light* have taken in the carbon dioxide.

Our conclusion: *Green plants take in carbon dioxide only in the light.*

Taking in Carbon Dioxide

How does carbon dioxide get into a plant? Let us use our microscopes. We can take a green leaf and with

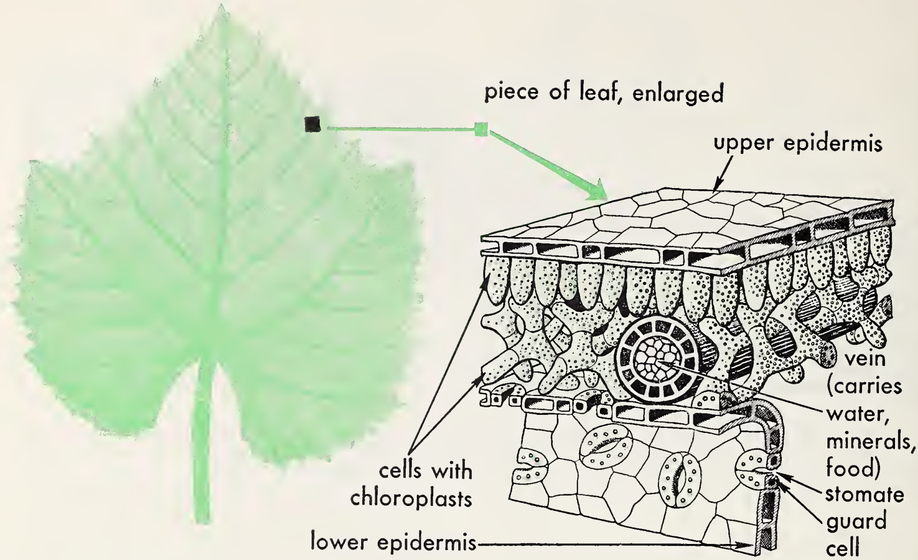


PHOTO BY HUGH SPENCER

179 *Project:* Get a green leaf and strip off its lower epidermis and examine it under the microscope. Do you see the openings, the stomates, as above? Now hold it up to the light. Do you see the veins which carry the plant's food, water, and minerals?

tweezers or forceps peel off the lower, clear, skinlike tissue, called the lower *epidermis* (ep-ih-DER-mis). Then we can put the tissue in a drop of water on a slide and examine it under the lens of the microscope. There we see many tiny openings in the lower epidermis. These openings are called *stomates* (STOH-maytz) (Fig. 179).

Carbon dioxide from the air enters the leaf through the stomates. It has been found that if these openings are closed by Vaseline, no carbon dioxide enters the plant.

Using Carbon Dioxide

What does the plant do with the carbon dioxide it absorbs in sunlight? Is it possible that plants make food only in sunlight?

It has been found that green plants make a kind of sugar, called *glucose* (GLOO-kohss), most of which is changed into starch and stored in different parts of the plant. By a simple test, using a weak solution of iodine, we can tell whether starch is present in any part of a plant. Iodine turns starch blue.

First, take a geranium leaf and cover half of it with black paper, leaving the other half uncovered (as shown in Fig. 181). Place the plant in sunlight. After 48 hours, take the black paper off and test both halves of the leaf for starch. Before we can make our test with iodine, we must first get rid of the green coloring matter in the leaf by boiling the leaf in alcohol. (Alcohol should not be boiled over an open flame. It catches fire. Use an electric hot plate or a double boiler.) Then we can stain the leaf in iodine to find out if starch is

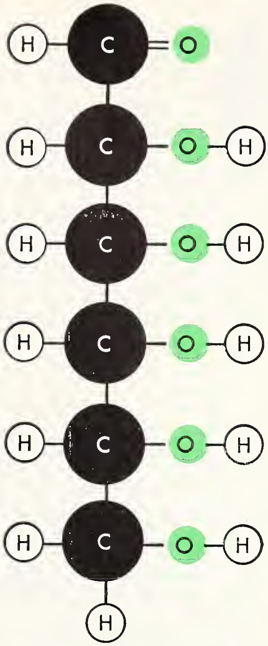
present. As soon as we remove the leaf from the iodine solution we can see that the half of the leaf that has been in sunlight is blue (Fig. 181). Therefore, it contains starch. The half of the leaf that was covered by black paper is unchanged. It contains no starch.

No matter how many times we repeat the experiment, we get the same results. Our conclusion is plain: *Green plants make starch only in sunlight.* Actually, plant sugar is made first and then changed into starch. We have found that this cannot take place except in the light.

How Do Green Plants Make Sugar?

Since green plants make sugar *only in light* and absorb carbon dioxide *only in light*, we may say that plants use carbon dioxide to make sugar *only in light.*

The chemist's formula for glucose sugar is shown in Fig. 180. This formula shows that glucose contains carbon, hydrogen, and oxygen. But carbon dioxide (CO_2) has only carbon and oxygen in it. Where does the plant get hydrogen? Water is a good source of hydrogen. You remember that the formula for water is H_2O, hydrogen and oxygen. We know also that plants take in large amounts of water.



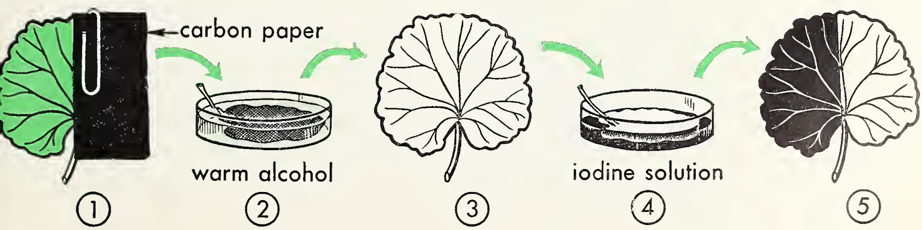
180 An idea of the make-up of glucose: 6 atoms of carbon + 6 atoms of oxygen + 12 atoms of hydrogen (all chemically joined) = 1 molecule of glucose.

From these materials, *carbon, oxygen,* and *hydrogen,* green plants make glucose sugar. They make glucose sugar *only in light.*

Green Plants and Oxygen

As plants grow, they take in materials from air and water to be used in making food. They also give out

181 *Project:* Take a green leaf and follow the directions on the opposite page. Why does iodine stain one half blue-black, showing starch is there? Why does the other half not stain blue-black?



a material very useful to us and to all animals. Let us see what that material is.

If we seal a snail in a tube filled with water plants, we find that the snail lives and grows. We can see that it gets its food from the water plants. The carbon dioxide given off by the snail in breathing is absorbed by the plant. But where does the snail get the oxygen it needs so that it is able to live?

By careful experiments, scientists have shown that in sunlight green plants give off oxygen. You can watch the plant Elodea give off small bubbles of gas very rapidly. This gas has in it a good deal of oxygen. It has been proved by many experiments that *in sunlight green plants give off oxygen.* We and all other animals use this oxygen for breathing.

Photosynthesis — A Key to Life

Whenever you have some facts which seem to be related, it is a good idea to try to put them together. We have, in the last few pages, gathered some facts about what green plants do in sunlight. They are shown here in the box.

Without foodmaking by green plants we could not live. Green plants are the world's food factories. Scientists call the foodmaking process in green plants *photosynthesis* (foh-toh-SIN-thuh-siss). *Photo* refers to the light which is needed. *Synthesis* means a putting together. Photosynthesis is a putting together of carbon dioxide (CO_2) and water (H_2O) in the presence of light. As a result, sugar, later made into starch, and oxygen are produced. These substances are used in one form or another by all living things.

Foodmaking in Green Plants

1. Green plants take in carbon dioxide only in light.

2. Green plants make sugar only in light.

3. Green plants use water in making sugar.

4. Green plants give off oxygen in light.

5. Putting these facts together we can say that, in light, green plants use carbon dioxide and water to make sugar, and that oxygen is given off during foodmaking.

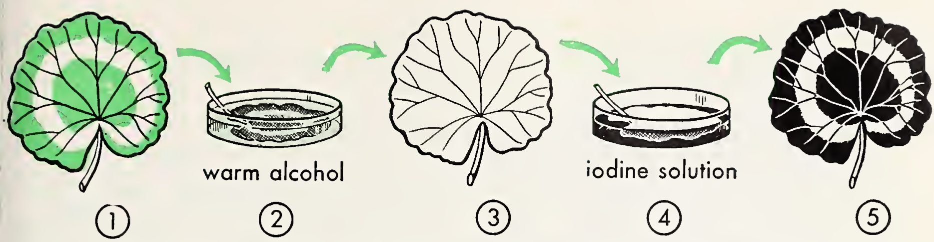
Energy for Photosynthesis

In photosynthesis, as in any other kind of work, energy is needed to get the work done. Where do plants get the energy for making sugar and starch?

Again, let us look at the facts we have just learned. From our experiments we have found out that plants make sugar only if they are placed in the light. Does this fact give you a clue to the source of energy for photosynthesis? Since it cannot take place in the dark, the energy for photosynthesis must come from the sun.

A Key Chemical

You have just been learning about one of the most important chemical reactions in the world, photosynthesis. Now you are going to find out something about one of the most important substances in the world. It is found in green plants.



182 Try this one. Take a leaf of the silver-leaf geranium, which looks somewhat like the leaf at the left. Put it in warm alcohol to remove the chlorophyll. (It becomes colorless.) Place in iodine solution. It is blue-black (showing the presence of starch) only where the chlorophyll was. Why? Compare with leaf at left.

With a straw, blow some carbon dioxide (CO_2) into water (H_2O) in a test tube in the bright sunlight. Then drop a little iodine into the test tube. Since the solution does not turn blue, we know that no starch has been made. CO_2 and H_2O are not enough to make starch. There must be some other substance in leaves to help them make starch. What is it?

Look at a leaf which has a white and green pattern, such as the silver-leaf geranium. Will starch form in both the green and white parts?

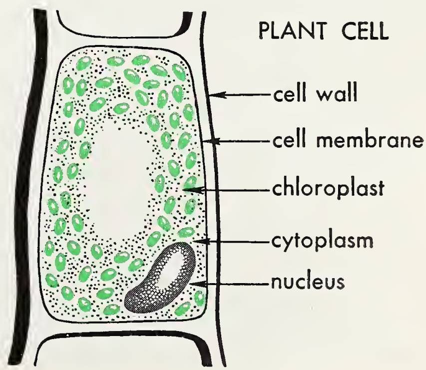
After the plant has been standing in the bright sunlight for a few hours, remove a leaf and test it for starch, as you did in the experiment on p. 356. After you take the leaf out of the iodine solution you find that no starch has been made in the white parts. Only the green parts of the leaf have starch (Fig. 182). You can try this experiment on many plants. You will always get the same results.

Scientists have found that it is only the green plants that make food. The reason for this, they have discovered, is that green plants have a substance in their leaves and stems that helps them to make sugars, like glucose, which may be changed into starch. This green substance is called *chlorophyll* (KLOR-uh-fil).

Look at Fig. 183. Do you see inside the cell of a green plant, tiny bodies called *chloroplasts* (KLOR-uh-plasts)? These have the chlorophyll in them. Scientists have discovered that, without chlorophyll or chemicals like it, plants could not make sugar. Without sugar, the basic substance for foodmaking in plants, all animals would starve.

Colorless plants, called *fungi* (FUN-jye), such as mushrooms and molds, have no chlorophyll. Because they

183 A green plant cell. The green oval bodies are the chloroplasts. The chlorophyll in them enables plants to make glucose.



have no chlorophyll, fungi cannot make their own food. They must, therefore, get their food from dead or other living things. A mushroom, for example, gets its food from dead or living leaves or wood. A fungus like bread mold gets its food from the bread or moist grain it grows on.

Testing the Truth of a Statement

The title of this chapter is "Food Factories of the World." Is this a true description of plants? Do the green-leaf factories really make food for all living things in the world? You might say that there are animals like the tiger and lion which eat meat only. They feed on zebras, wild cattle, or deer. But what do zebras, cattle, and deer eat? Their food is grasses and other green plants. Without plants, then, the tiger and lion would have no food.

Plant-eating animals, such as cattle and poultry, also produce milk and eggs, two very important foods. Green plants do appear to be the basic food factories of the world.

The Carbon Dioxide-Oxygen Cycle

From what you have learned in this chapter, do you think that a goldfish would live if it were put into an aquarium where green water plants, but no other food, were growing? Could the fish live, even though the aquarium were sealed with a glass plate?

Even though the aquarium is sealed, the fish will get both food and oxygen from the plants, but the plants also will be helped by the goldfish. As the fish breathes out carbon dioxide, the plants will take in this gas. The plants, then, with carbon dioxide, water, chlorophyll, and sunlight, can make food for themselves and the goldfish. They will also give off oxygen, which the goldfish needs. The sealed aquarium is a small world in itself.

Can you see that our world is like the small world inside the aquarium? With millions of other living things, you are giving off carbon dioxide. This carbon dioxide goes into the air, where it is taken in by green plants.

 An aquarium. These angel fish and plants live together, each depending on the other. Plants give the fish food; the fish give the plants minerals and carbon dioxide.

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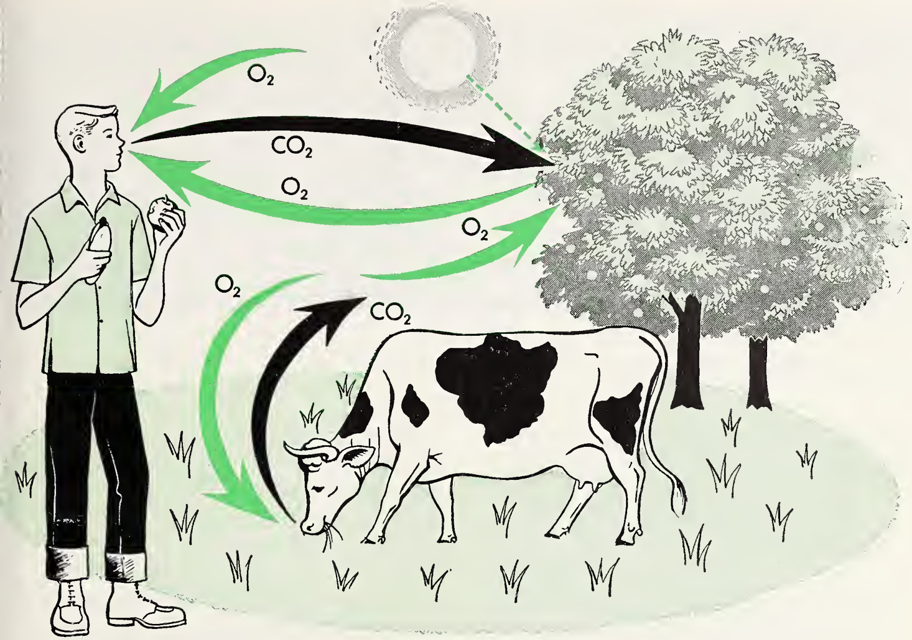


185 Animals take in oxygen (O_2) and give off carbon dioxide. So do plants. So do you. The O_2 is used in burning food. But green plants (during the day) use the sun's light and take in carbon dioxide (CO_2) to make food. In *using* CO_2 they give off O_2.

Right now, as always, you are taking in air and using the oxygen in it. This oxygen may have been given off by green plants, just as oxygen was given off by the plants in the aquarium. Animals take in the oxygen that plants give off during photosynthesis; plants take in the carbon dioxide that animals breathe out. Plants then use this carbon dioxide as a raw material in making food. In Fig. 185 is a diagram of the give-and-take of oxygen and carbon dioxide.

One other point! Plants also use oxygen just as human beings and all animals do. Scientists have proved that green plants take in oxygen and carbon dioxide at the same time, and that plants, like us, use oxygen in the burning of food, that is, in breaking food down for their cells to use.

RAW MATERIALS FOR THE FOOD FACTORIES

Everybody knows that factories would soon have to shut down if their supplies of raw materials were cut off. If even one material were missing, the product could not be made. The same is true of green plants.

Plants Have Many Needs

Carbon dioxide, water, chlorophyll, and sunlight are not enough for the growing of strong, sturdy

U.S. DEPT. OF AGRICULTURE

186 An experiment on the effect of fertilizer. *Left*, poor soil with no fertilizer; *right*, the same soil, with fertilizer added.

plants. A plant needs other materials to build up its own roots, stems, and leaves. It must have certain substances which it gets from the minerals in soil and water. Some of the substances needed are phosphorus, nitrogen, potassium, iron, and magnesium. Without iron and magnesium plants could not make their chlorophyll. You need these substances, too. You get them from the food you eat, but a plant must get them from the soil in which it grows (Fig. 186).

A plant cannot get these substances — iron, magnesium, potassium, nitrogen, or phosphorus — from dry soil. They must be dissolved in water before the plant can use them. This is another reason why water is so important to plants.

In the deserts of our country, there is very little plant growth during most of the year. Minerals are present in the soil, but there is so little rainfall that they are not dissolved. Therefore, the plants cannot use them. During the time of early spring rains, the desert seems to come to life. The cactus plants grow and bloom and make seeds. Other plants seem to come up from nowhere, but they really come from the seeds in the sand. They grow quickly, bloom, and make seeds. Then, as the days pass, they die in the hot sun. The seeds are left, however, to grow into new plants when spring rains come the next year.

Much desert land in the West has been made useful for growing plants by having water brought to it through pipes and ditches. This is known as *irrigation* (ih-ruh-GAY-sh'n) (Fig. 187). About 500,000 acres of land in the Imperial Valley in California, as well as large parts of Utah, Arizona, New Mexico, and Texas have been irrigated by bringing water from reservoirs, lakes, and streams many miles away. In the state of Washington, the Grand Coulee Dam on the Columbia River has brought water to more than a million acres of land. Each year more waterless land in the western United States is made into good farmland by irrigation. When water is brought to the soil, the minerals in the soil dissolve and then can be used by plants.

How much water does a plant need? The amount differs with the season and with the kind of plant. Plants use more water in warm weather than in cold. Plants with thin leaves use more water than plants with thick leaves. Gallons of

water will evaporate from the thin leaves of a maple tree in warm weather. However, the thick skin (epidermis) of a cactus will lose very little water.

It is during the growing season, spring and summer, that plants use great amounts of water. For instance, a big beech tree, 100 years old, takes from the soil about 65 barrels of water during a season. One corn plant may use five to ten times its own weight of water a day.

Do you have plants in your home? Make a study of your house plants to find out how they should be watered. In "Adding to Your Library" at the end of this chapter, you will find the title of a good book on the care of house plants.

Plants, like all living things, cannot live without water and the mineral substances dissolved in it. Animals need the soil minerals they get from eating plants if they are to grow and be healthy. Their life and yours depend upon these minerals.

From the Soil to the Plant

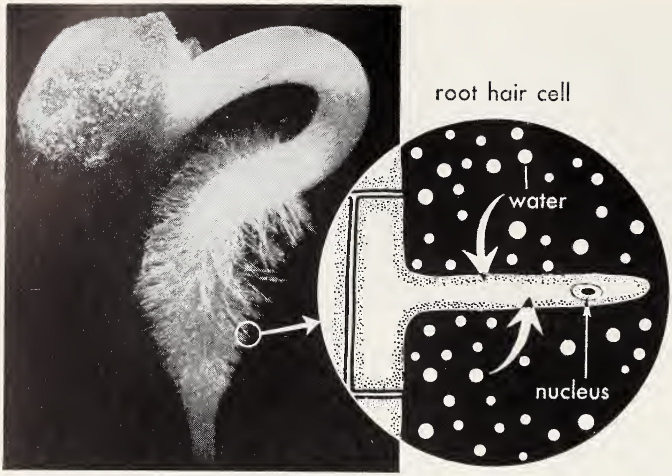
How do phosphorus, magnesium, iron, nitrogen, potassium, and the other needed substances get into the plant? If you have set out plants in your garden or helped to plant a tree, you may have an idea. You know how careful you must be not to injure the roots of the plants or the tree, or the plant may die very quickly. Let us find out how the roots help the plant to get its food.

Take some radish seeds and place them between two moist pieces of blotting paper. In two or three days, look at the seeds. Notice the white roots each seed has sent out. Even with your naked eye you cannot fail to see a fuzz on the root. This fuzz is a mass of small, threadlike *root hairs* (Fig. 188).

If you look at root hairs under the microscope, you see that each one is a long, thin, hollow cell, extending out from the root. Each plant has

187 Water brought by irrigating ditches like this one will make a desert grow food.

SOIL CONSERVATION SERVICE



188 *Project:* Plant a radish seedling. In two or three days, examine the root hairs under the microscope. What you may see is diagramed at the right. Water enters the root hair cells. How is the root hair cell fitted to absorb water?

PHOTO BY HUGH SPENCER

millions of these root hairs. Does the water from the soil, with its dissolved minerals, enter the plant through these root hairs? Some experiments, to do at home or at school, will help to answer this question.

Root Hairs at Work

Take a glass of water and let a drop or so of red or blue ink from your pen fall into it. When the ink colors the water entirely, the ink has spread evenly through the water.

Then add a pinch of table salt to another glass of water. Watch it disappear in the water as it dissolves. Even though it can't be seen, you will still be able to taste the salt in the water. The dissolved salt has spread through all the water in the glass. This spreading of one substance evenly through another is called *diffusion* (dif-YOO-zh'n).

Scientists explain the swift spreading of substances through water in this way: You know that salt is made up of molecules. These molecules are always moving about, some more slowly, some rapidly. As they move about in the water, they mix with the water molecules until they are spread evenly through the water.

Not all substances will dissolve in water. For instance, starch molecules do not. Try some starch in water and compare it with the salt experiment. The starch settles to the bottom. Its molecules do not diffuse evenly through the water, as the molecules of salt do.

Fortunately, the minerals in the soil which are needed in plant growth can be dissolved in water. And now let us find out how soil minerals enter the root hairs of plants by diffusion.

Since each root hair is a cell, it has a *membrane* around it. Let us find out if substances can diffuse through membranes.

Take a piece of plain cellophane (which will be the membrane) and shape it into a bag.[1] Put some salt solution into it. Tie the bag with a string and examine it to see if it leaks. Place the bag in a glass of

[1] The cellophane from a package of cigarettes is not useful for this purpose since it is treated to keep water out.

water. After a few hours taste the water in the glass. It is salty. The salt must have diffused through the cellophane membrane into the water in the glass. In the same way, salts found in the soil diffuse through the living cell membranes of root hairs (Fig. 189).

Carrying the Minerals Upward

How does water carrying the dissolved substances get to every part of the plant? Cut a small piece off the lower end of a stalk of celery and place the stalk in a glass of water colored with red ink. After several hours you can see that the red liquid has climbed up the stalk through tubes inside the stem.

Under the microscope, the tubes or ducts in a plant like corn can be plainly seen. The ducts are in groups like a bundle of straws (Fig. 190).

Scientists have found that some of these ducts carry water with its dissolved substances up to the leaves. Other ducts carry the food manufactured in the leaves downward to all parts of the plant.

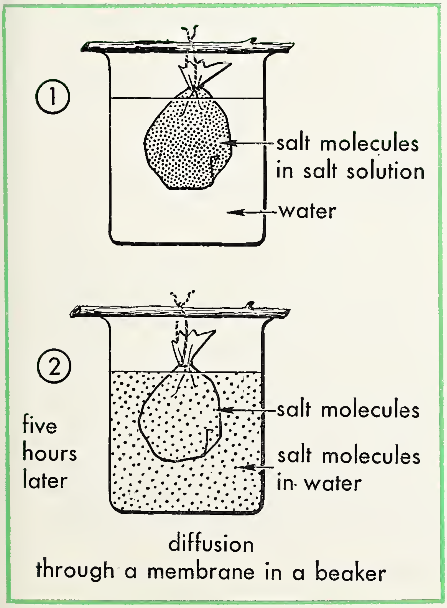
Storing Food

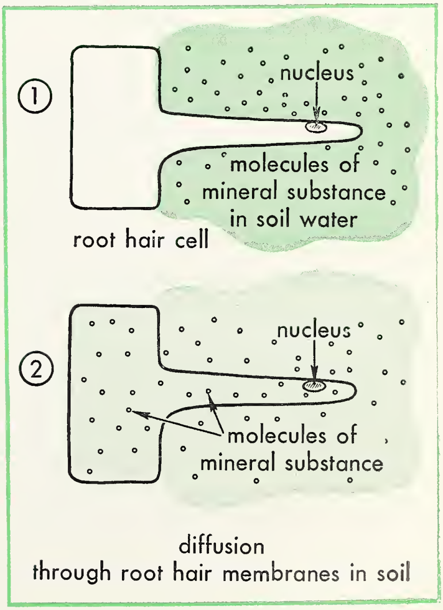
Some of the starch or sugar a plant makes is stored or made into other foods. Seeds contain starch, oil, or sugar. Starch may be stored in underground stems. For example, the white potato is really an underground stem. Starch or sugar may also be stored in roots like those of the carrot, beet, radish, or sweet potato. And, of course, sugar is found in most fruits.

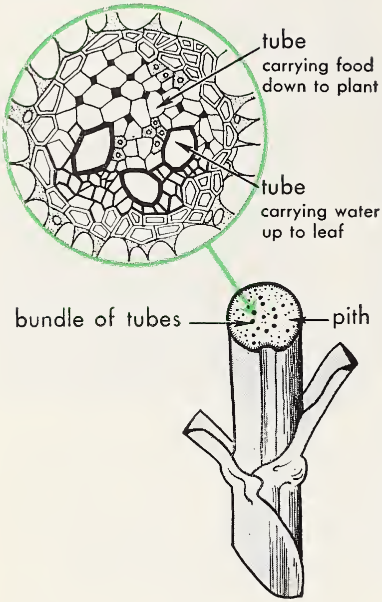
Most nuts and some seeds, like those of cotton and flax, also have oil in them. These vegetable oils are stored foods made by the plant.

You have already learned how im-

189 *Diffusion:* Molecules of substances dissolved in water move about until they are spread equally throughout. The molecules will travel through membranes — especially those of root cells.







190 The next time you go out into the fields, look at the cut edge of a corn stalk to find the bundles of tubes. Where does water enter the plant?

portant vitamins are to your health. Plants make vitamins, too. You know, also, that plants store minerals needed for your health and growth.

A Look Back at Photosynthesis

How is the green plant like a factory? It takes raw materials and makes them into other materials. We may say that oxygen and carbon dioxide from the air, and water with its dissolved minerals from the soil, are the raw materials. Sunlight yields the energy to run the factory. The chloroplasts in the leaf cells are the workers. Food is made by the green plant factory (Fig. 191). In the box below are the steps in foodmaking by green plants, which we call photosynthesis.

Steps in Photosynthesis

1. Water (H_2O) and minerals are absorbed by the root hairs of the plant.

2. The water and the minerals dissolved in it travel up the ducts to the leaves.

3. Carbon dioxide (CO_2) enters the leaves through openings called stomates.

4. In the leaves, chlorophyll brings the carbon dioxide and water together to make sugar. The energy for this chemical reaction comes from sunlight.

5. The ducts carry the manufactured sugar to all parts of the plant. Some of the sugar is changed to starch and stored in roots, seeds, and stems. Some is used for plant growth.

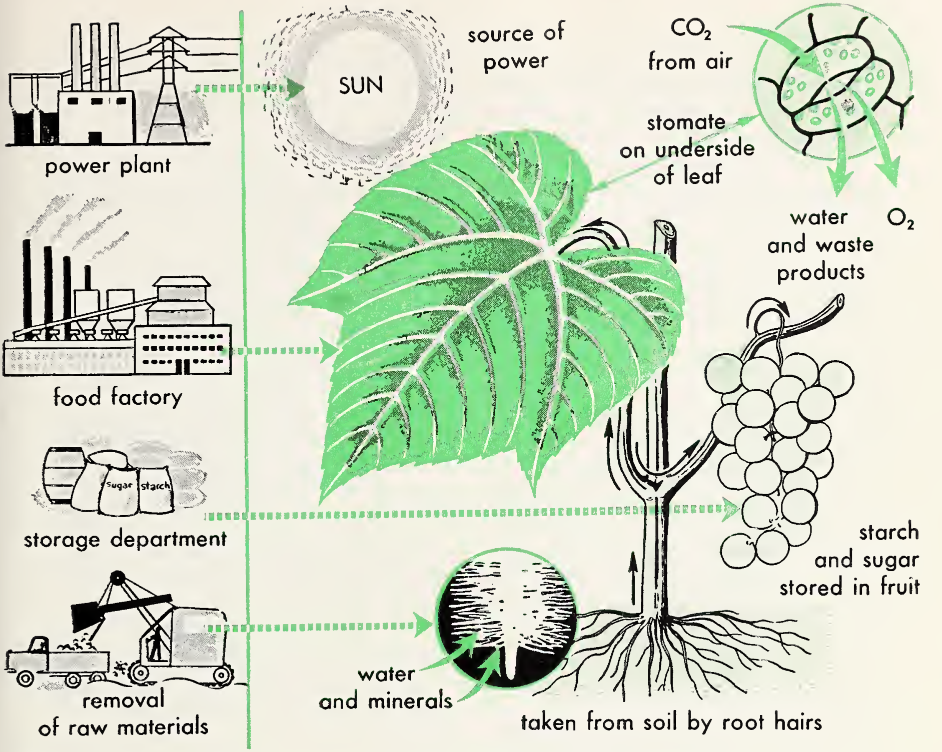
6. Oxygen and water are given off from the leaves through the stomates.

Because green plants can carry on this work of photosynthesis they are, indeed, "the food factories of the world."

Radioactive Substances and Food Production

You may think that we have learned all there is to know about how plants make and store food. We are only just beginning. Scientists are still learning much about photosynthesis. They are finding out some of the facts by using radioactive substances (Unit 5, p. 310).

As soon as radioactive substances were made in atomic piles, scientists began to use them to find what really



191 The plant as a sugar and starch factory. Study this diagram carefully and see why green leaves may be thought of as "the food factories of the world."

happens in photosynthesis. For instance, they wanted to find out what really happens to carbon dioxide when it enters the plant. In their study, they used radioactive carbon from the Oak Ridge plant of the Atomic Energy Commission.

Radioactive carbon gives off rays that cause "clicks" in a Geiger counter (Fig. 153). Scientists combined radioactive carbon with oxygen to make radioactive carbon dioxide. Can you guess why? They put growing plants in a chamber in which this radioactive carbon dioxide had been placed. As soon as the carbon dioxide entered the stomates in the leaves, the scientists were able to follow its path with the Geiger counter. They discovered an important fact. They found that before carbon dioxide is built into sugar, it is first built into a substance which they had not known about. This substance, whose formula is not yet known, seems to help in the making of sugar.

Radioactive Substances and Minerals in Plants

Scientists are using radioactive substances to study another plant problem: What happens to the minerals taken in by the roots?

Substances with radioactive phosphorus in them were placed in the soil. As the phosphorus was taken in by the plant, the scientist could follow it through the plant with his Geiger counter. In ways like this, it was found that, in corn plants, phosphorus collects in the kernels of corn. Elements like zinc collect where the leaves join the stalk.

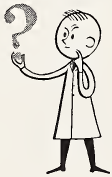
Experiments of this sort are going on at many universities, such as the universities of Pittsburgh, Wisconsin, Minnesota, Hawaii, Texas, California, and of Purdue (Indiana) and Cornell (New York). With the help of scientists working in many places and using new radioactive materials, we shall soon know much more about plant growth and photosynthesis. Then we can have more and better food.

Supplying Food to the World

To make and store food needed by the nation requires hard work by farmers, scientists, mechanics, and men and women of many other walks of life. It is on the farm that the most important business in the world goes on — that of growing food. The farmer is the expert in this very important work. He must know how to do many things.

Plants must produce more plants, and animals must produce more animals; that is, they must *reproduce.* Helping with this work is one of the jobs of the farmer. The farmer can feed the world because he knows his job. But he cannot feed the world unless his soil supplies his plants with the water and minerals needed for the plants to make food. Therefore, the farmer must be sure that his soil is rich, and that it has in it whatever the plants need.

The soil is so important to living things everywhere that it has been called "brown treasure." The next chapter tells you why this is so, why soil is treasure to you — to every one of you.



LOOKING BACK

Tool Words

If you understand the key words below, you can place many of them correctly in the spaces in the statements which follow them. Do this by copying the statements in your notebook. DO NOT MARK THIS BOOK.

carbon dioxide	fungus (pl., fungi)	radioactive carbon dioxide
chlorophyll	glucose	root hairs
chloroplasts	minerals	starch
diffusion	nitrogen	stomates
ducts	oxygen	
epidermis	photosynthesis	

1. Green plants take in soil water containing dissolved . . . .
2. In the light, green plants take in . . . through . . . in their leaves.

3. Green plants make . . . only in sunlight.

4. Probably the most important chemical reaction in the world is called . . . .

5. Inside the cells of green leaves are tiny bodies called . . . , which have in them the substance . . . .

6. . . . plants have no chlorophyll.

7. By doing experiments with . . . , scientists have been finding out how carbon dioxide is used by the plant.

Test Yourself

Copy the phrases in List A. Before the phrase write the letter of the word from List B that is most related to it. DO NOT MARK THIS BOOK.

List A	*List B*
1. the green coloring matter of plants	*a.* bromothymol blue
2. a gas given off by plants during photosynthesis	*b.* calcium
3. a dye which shows the presence of CO_2	*c.* carbon dioxide
4. a food substance stored in plants	*d.* chlorophyll
5. an opening in a leaf through which water and gases pass	*e.* diffusion
6. a gas needed in photosynthesis, to make sugar	*f.* hydrogen
7. the process by which dissolved minerals get into plants	*g.* nitrogen
8. the most plentiful gas in the air	*h.* oxygen
9. source of plant energy	*i.* solution
10. minerals dissolved in water form a ——	*j.* starch
	k. stomate
	l. sun
	m. water

GOING FURTHER

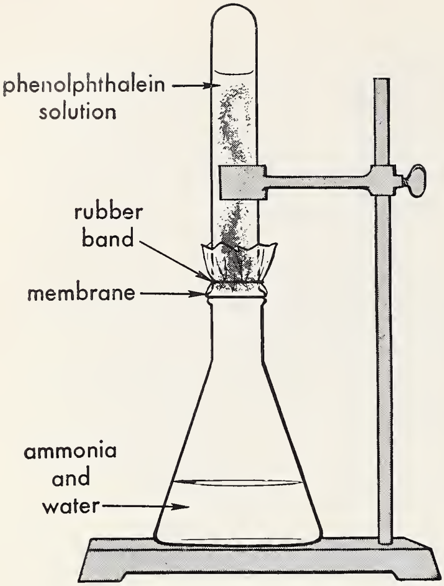
In the Laboratory and Field

1. *Examining stomates.* Take the leaves of the plants you find around your school. Use a microscope to make your examination. Are there stomates only on the undersurface or on the top surface, or both? Are there more on one surface than on the other? Keep notes.

2. *Finding out how plants take in* CO_2. Vaseline will close the stomates. Take a plant like a geranium and, without removing the leaves from the plant, smear the underside of one-half a leaf, three-quarters of another leaf, and then an entire leaf with Vaseline. Do the same for the upper surface of other leaves. Place the plant in the sunlight. Test the leaves for starch (Fig. 181).

3. *Experiment with photosynthesis.* Take two bell jars, each with openings at the top. Put a geranium under each jar. Also, put a wide-mouthed jar of limewater (which takes in CO_2) under one. Now seal the bell jars.

Place both jars in a dark place for 24 hours to rid the leaves of starch. Now place both jars in the light. After a day in the light, test each one for starch. What is the effect of lack of CO_2?



4. *Diffusion.* By using certain chemical reactions you may be able to "see" how diffusion takes place. Fill a test tube with water and add a few drops of 1% phenolphthalein (fee-nohl-THAL-een) in alcohol. (To make this solution, dissolve 1 gram of phenolphthalein in 100 cubic centimeters of water.) Now with a rubber band fasten a goldbeater's membrane or a piece of cellophane around the mouth of the tube. Invert this over an open bottle of ammonia. Molecules of ammonia diffuse through the membrane and react with phenolphthalein to color it red. Watch the spread of the red color as the diffusion of ammonia molecules takes place. (See figure above.)

Put on Your Thinking Cap

A boy did the following experiment. He grew tomato plants in soil which had all the substances commonly found in soil, except magnesium. The green leaves of his plants were speckled with white; some turned yellow, and others fell off. From this the boy could conclude: (1) that magnesium is needed to form chlorophyll; (2) nothing, because a control experiment was lacking; (3) that magnesium is necessary for proper growth; (4) that speckling or yellowing is a result of a lack of magnesium.

Select the conclusion you think is the correct one and give the reason for your selection. If you think you can improve on this experiment, plan a better one and show it to your teacher.

Adding to Your Library

1. *The Guide to Garden Flowers* by Norman Taylor, editor, Houghton, 1958.

2. *Gardens and Grounds That Take Care of Themselves* by Amelia Leavitt Hill, Prentice-Hall, 1958.

3. *Strange Plants and Their Ways* by Ross E. Hutchins, Rand McNally, 1958.

4. *Edible Wild Plants: of Eastern North America*, revised edition of a useful book, by Merritt Lyndon Fernald and others, Harper, 1958.

5. *The Wonders of Seeds* by Alfred Stefferud, Harcourt, Brace, 1956.

6. *Play with Leaves and Flowers* by Millicent E. Selsam, Morrow, 1952.

7. *Pruning Made Easy* by Edwin F. Steffek, Holt, 1958.

8. *How to Identify Plants* by H. D. Harrington, Sage Books, 2679 S. York St., Denver, Colo., 1957.

Careers for You

More and better-trained *farmers* are needed to produce better food crops. *Botanists*, skilled in the study of plants, are needed for research work. *Chemists* who are skilled in the chemistry of plants are in demand. Many chemists are working in the branch of science known as *chemurgy* (KEM-er-jee). They find ways in which industry can use what is made in the bodies of plants as they grow (such as the use of the soybean oil in paints). *Horticulturists*, skilled in growing flowers, fruits, and vegetables in the field and in greenhouses can help to supply food for our nation.

Teachers of biology will always be in demand in high schools and colleges.

CHAPTER 19

Better Food from Better Soil

There is a line from your dinner table to the soil, and to the farmer who tends it. He grows the crops and raises the animals which feed on the plants. Soil is "brown treasure" that is yours to use wisely.

Do you live in Texas or near there? Wherever you live, what happened to the soil in Texas a few years ago is important to you.

If you live in the northern or eastern part of the United States you may not have heard about the troubles, very bad troubles, the farmers of Texas had in the years from 1950 to 1953. In the western half of the state they had had a four-year drought. By the summer of 1953 pastures no longer grew enough grass for the range cattle; crops failed, and the farmers lost millions of dollars. Why? The topsoil had blown away in dust storms. The water in the Rio Grande River fell so low that farmers in the Rio Grande Valley could no longer get water from the river.

Could these troubles have been prevented? No one, of course, could have brought the moist winds from the Pacific over the Rocky Mountains, but perhaps something could have been done to save the topsoil and the water.

In northern Texas and in Oklahoma the farmers did not do so badly as they had in the 1930's. At that time

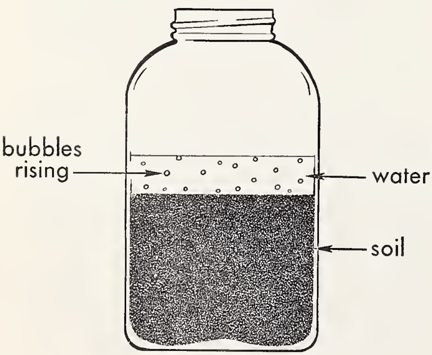
the land had become a dust bowl. The dry soil drifted in great heaps along fences and around buildings. Growing things were killed by the dust. Great clouds of dust blew through the air, even as far east as the Atlantic Ocean.

Why were conditions in northern Texas and Oklahoma better in 1953 than in the 1930's? The farmers had learned a lesson. They had learned how to plant their crops so that the soil would not blow away when a dry spell came. They had learned, too, how to save for their crops every possible drop of rain. In other words, they had found by bitter experience that good farming practices pay, as well as wise use of soil and water.

To keep the topsoil and make it better is the secret of producing better food for our nation of over 160 million people. To do your part in this job of conserving and improving soil, you will need to understand:

1. What soil is.
2. How soil is lost (eroded).
3. How soil is saved and improved.

192 Water has just been added to garden soil in this jar. Where do the bubbles you see rising come from?



WHAT IS SOIL?

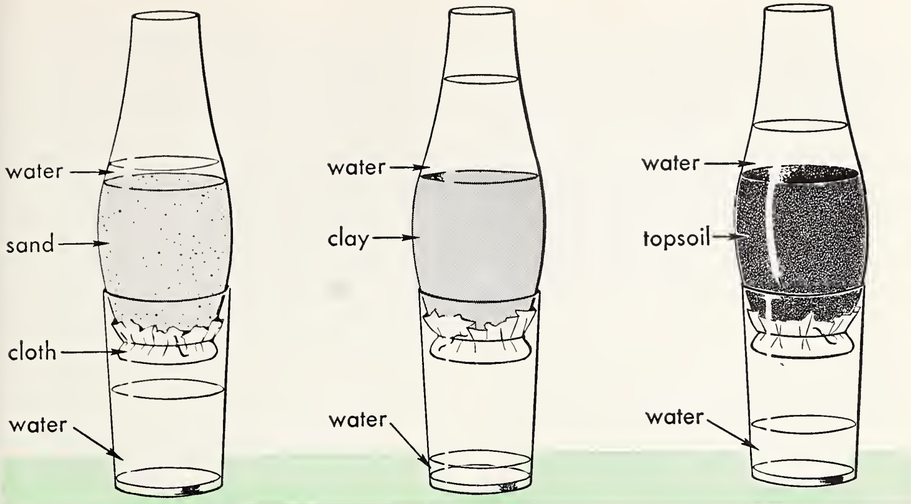
Go out to your garden or to the woods. Scoop out about a quart of *topsoil*, which is the name given to the top layer of soil in which most plants grow.

Put this soil into a two-quart glass jar. Then add water to about two inches over the soil line (Fig. 192). You will see air bubbles leaving the soil. As soon as the soil becomes soaked with water, the air bubbles will stop coming up to the surface. Topsoil holds air, which plants need for their growth. But soil under water holds so little air that plants do not grow well in it.

The amount of air in topsoil depends upon the kind of soil. What is soil made of? Shake up the soil and water in the jar, and then let the mixture settle overnight. What do you find the next day? The soil particles have settled in layers, with the heaviest particles at the bottom, and the smallest and lightest at the top. At the bottom there may be sand or gravel, then silt (fine particles of soil), then clay, made up of the finest particles. At the top you may find floating bits of decaying plant material. These bits of leaves, stems, or roots, as they decay, become part of the soil. This material, called *humus* (HYOO-mus), helps to feed the growing plants.

Humus has in it minerals that plants need for growth. It helps the growth of soil bacteria, earthworms, and other things that live in good topsoil. Humus is very useful, also, in holding water in the soil.

Almost all soils are made up of different proportions of small rocks, bits of rock, sand, clay, and humus.



193 Each lamp chimney holds the same amount of different kinds of moist soil. The same amount of water has been added to each chimney. Why do different amounts of water run through the soils into the glasses?

An experiment will show you the difference in the way these kinds of soil hold water.

Get about a cupful of each kind of these soils: (1) sand, (2) clay, and (3) soil with a good amount of humus. Get three glass funnels with wide spouts or three kerosene-lamp chimneys. Tie a thin cotton cloth over the bottom opening, and set the funnel or chimney in a drinking glass. Then pour the sand into one container, the clay into the second, and the humus soil into the third. Now pour one cup of water into each container (Fig. 193). Compare the amount of water draining through the three containers. Also note how long each kind of soil holds the water. How would this affect plants growing in the soil?

Because clay soil holds water, its very fine particles cling together. The clay packs so hard that most plants cannot grow well or get enough air around their roots. Soils which are made up mainly of clay are hard to work. They pack hard when dry, and are like bread dough when wet.

Sandy soils dry out very quickly. In a dry season the plants do not get enough water, because it drains away so fast. Sandy soils are often lost, because wind blows them away.

Good soil is a mixture of three types of soil material: clay, sand, and humus. We call this soil mixture *loam*. In loam there are enough large particles (sand and humus) to keep the soil porous, and enough small particles (clay) to take in water. The humus in loam also holds water.

Examine the soil from a garden. Is it largely clay or sand, or is it loam? It may be clay loam or sandy loam, but if it has humus in it, you can be quite sure that your garden plants will grow. Of course, they will need water and good care.

Topsoil has different depths in different parts of the country. In some places it is several feet deep; in others, only a few inches. In some parts of our country, winds and water have taken away much of this precious topsoil on which our food supply depends. Let us find out more about some of the materials in the topsoil.

Experiments on Soil Materials

Take another quart of garden or woods soil and pour a quarter of a cup of it into a metal pan. Cover the pan and heat the soil gently over a flame. Look at the inside of the cover. You will see drops of water which have been driven out of the soil. Without water, the soil minerals would not dissolve. They could not be used by plants.

What does soil water have in it? Take another quarter of a cupful of soil and a quarter-cup of distilled water and shake them up well for five minutes. Then filter the water from the soil. Put the filtered water into an evaporating dish and heat the dish until all the water has evaporated. As a control, put a quarter-cup of distilled water with no soil in it into a second evaporating dish. When the water in both dishes has evaporated, you will find whitish mineral salts left in the dish where the soil water was, but not in the other dish. From this experiment you can see that soil water has dissolved minerals in it.[1]

[1] Some of the minerals which scientists find in soil are compounds of calcium, phosphorus, nitrogen, iron, sulfur, potassium, magnesium, sodium, manganese, and boron. These minerals are very important not only to plants but also to your own health and growth.

Water and minerals are not the only things found in soil. You have found that out if you have ever dug for worms. You may also dig up insects, snails, and other animals. Some counts of the number of small animals in topsoil have been as high as 13,500,000 in an acre. These worms and other animals, especially the earthworms, are a real help to man. They loosen up the soil as they crawl through it and make it easier for water and air to enter. The earthworms even bring little piles of soil to the top of the ground at night. Have you seen these worm castings? Earthworms get their food by swallowing soil and breaking down parts of it. When the soil leaves their bodies, it is rich in nitrogen, which all plants need for growth. Charles Darwin, a great English scientist, once wrote that a stony field he had seen was completely covered with soil in about ten years by the work of the earthworms in it.

Just as important to us as the animals are certain single-celled plants, the *bacteria*. These can be seen only under a microscope. Like the fungi, bacteria are colorless plants and cannot make their own food. The best soil has the most useful kinds of bacteria in it. Some of these bacteria take nitrogen from the air and change it into substances which plants use. Other bacteria cause leaves and other plant and animal materials to decay, thus adding humus to the soil.

Scientists have also found that some microscopic fungi in the soil can be used to make medicines. For instance, some make penicillin.

Truly, fertile soil is the treasure box of the world! It is worth more to nations than all the gold and precious stones they could find.

HOW SOIL IS LOST

It has taken hundreds and even thousands of years to build up our soil. It comes from rock which has been broken down by wind, by water, by ice, and by tree roots. This wearing away, or erosion, goes on all the time. Not only is rock eroded, but so is soil. By being careless, man has speeded up the natural erosion of soil in some places to a very dangerous point.

Losing Soil by Losing Roots

There were some 822 million acres (nearly 1,300,000 square miles) of forests in the time of the Pilgrims. Wave upon wave of settlers came. As they pushed westward, they cut down more and more trees. They destroyed the forests wastefully. What was still worse, they planted no new trees. In cutting trees for lumber, the settlers paid no attention to saving the young trees for future growth.

In these forest lands, the pioneers often cleared away the trees so they could plant their crops. After a few years, they moved on to new land, cut down more trees, and began again.

The early settlers had all the West before them. The prairie grasslands were so fertile and so easily plowed that vast areas of grain were planted. The prairie grasses had held the soil in place, but the plowed soil was often left bare after the grain was harvested. Then the wind could blow away the fertile topsoil. The damage had begun.

In cutting down the trees and plowing under the roots of the prairie grasses which held the soil, the settlers had left the soil open to erosion. Heavy rains would wash it away and carry it down the streams. This waste of good topsoil made the land poorer and poorer.

The natural forests in the East are almost gone; in fact, 96% of the natural forest in our country is in the western states. Federal and state governments now try to protect our natural forests. They have set aside areas, such as state and national parks and forests. Industry, too, is cutting timber carefully so that forest lands will produce good timber for years to come. Farmers are encouraged to plant trees on sloping land so that soil will not easily wash away. Schools observe Arbor Day in early spring to stress the importance of conserving soil and planting trees. You will gain from these efforts being made to repair the damage of past years.

Trees give us many important products, such as lumber, pulp for paper, boxes for shipping, and the furniture in our homes. Their greatest importance, however, is in holding the soil in place, so that rain falling on hillsides will not rush down so fast that it will take the soil with it.

When trees are cut, their leaves can no longer break the fall of the rain. The carpet of leaves on the ground can no longer act as a sponge to soak up the water. The rain then washes topsoil down into the valleys. Soon the heavy clay or sand beneath the topsoil is uncovered. It, too, washes down into the valleys, where it covers the fertile topsoil. Worse than that, the rain tears gullies in the hillside until the land is worthless (Fig. 194). Furthermore, the streams may become so muddy from the silt washed into them that plants and fish cannot live in the water. Are there

U.S. FOREST SERVICE

194 A forest, ruined. Trees cut without replanting others leave a barren waste like this. And the rains wash the soil into the rivers.

any streams in your neighborhood where fishing used to be good? What has happened to the fish in these streams?

Losing Soil Minerals

Soil without its minerals is useless for plant growth. As you have read, plants use large amounts of nitrogen, phosphorus, potassium, and calcium for growth, as well as small amounts of iron and other substances. If the same crops are planted year after year, these minerals are used up, and the plants will lack what they need for growth. The soil is then said to be *depleted* (deh-PLEET-id).

In one recent year, for instance, it was estimated that crops used 700,000 tons of phosphorus, and another 900,000 tons of phosphorus were washed away. Still another 900,000 tons were lost from pasture lands. Add these up, and you have a loss in one year of 2,500,000 tons of phosphorus in the United States alone.

Phosphorus and other minerals can be put back into the soil by using fertilizers. However, during that one year, farmers put back only 1,100,000 tons of phosphorus, less than half the total loss. This story is true for other substances as well, especially nitrogen, potassium, and calcium. If this loss were allowed to go on year after year, the soil and the plants on it would become poorer and poorer. The farmer would finally have to give up his farm. Depleted soil means low production of food.

Soil that is being blown or washed away and soil that is losing its minerals are the problems of all who are growing food for the world's people. How can these problems be solved?

A Farmer Tries to Solve His Problem

Let us see what a farmer whom we shall call Mr. D actually did for his soil. He had not always owned his farm. He worked hard and finally bought a farm whose soil showed some depletion. Also here and there some of the sloping fields were eroding. He said, "I know it's poor land, but I think I know how to make it right again."

First, he knew that good soil

1. Can hold enough water for growth.

2. Has all the minerals for good growth.


AMERICAN FOREST PRODUCTS INDUSTRIES, INC

195 In the Pacific Northwest, fir and hemlock forests as far as the eye can see. Man has learned from scenes like the one opposite. He is taking care of his forests.

3. Has a topsoil which cannot be blown or washed away.

Second, Mr. D knew about the experiments of the United States Soil Conservation Service. This Service gave him this information (Fig. 196).

1. An acre of land with a slight slope planted with potatoes year after year lost about 60% of its rainfall. It also lost about 1,000 pounds of soil in 19 rainy days.

2. An acre of land planted in grass lost only about 0.2% of its water, and almost none of its soil.

3. An acre of forest land lost about 0.5% of its water and practically none of its soil.

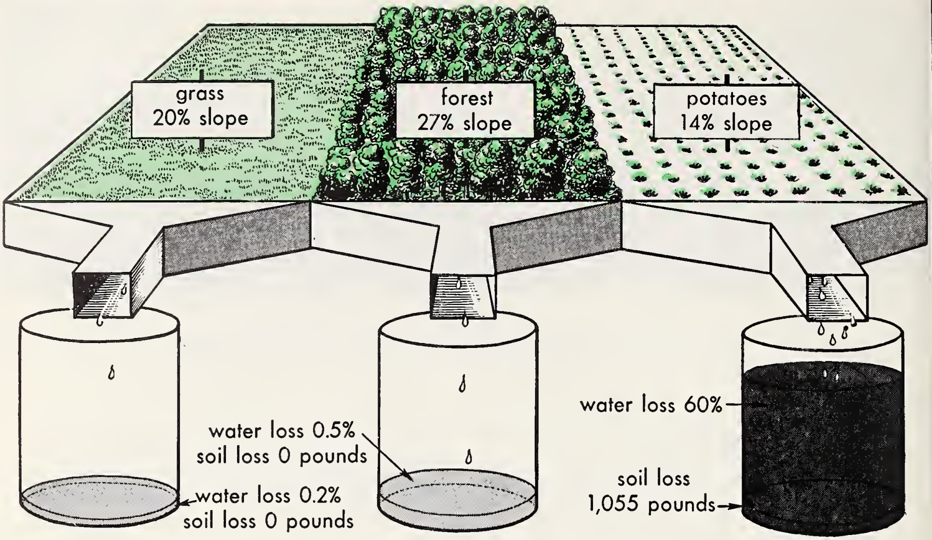
Mr. D had another helping hand in solving the problem of improving his new farm. It was the United States Department of Agriculture.[1] From it, he got a great many facts about what plants need for best growth. For instance, he learned that scientists had grown green plants in chemical solutions to find out what they needed for best growth. To some of these solutions they had added different amounts of such minerals as calcium and potassium. After many years of work they discovered how much of each mineral was needed for the best plant growth. Let us see now what Mr. D did.

[1] Many of these important facts are found in a book called *Soils and Men*. You can get a copy at the library or from your Congressman.

SAVING AND REMAKING SOIL

With all these facts and experiments to help him, farmer D went to work. First, he planted his eroded sloping fields in grass and clover, plants with roots that would spread out and hold the soil in place. He used fields with steep slopes for pasture, never for crops. On other, steeper slopes, he planted trees. In addition, he planted trees around fields to help hold any soil which had washed down and to prevent winds from blowing the soil away.

He left no bare fields to blow away after grain was harvested. With his grain he planted clover or other grass seed to come up and cover the land and hold the soil. The next year grain would be planted in another field. The clover and grass in the first field would produce a hay crop. By *rotating crops* in this way, the farmer also improved his soil. Such crops as clover and alfalfa added nitrogen to the soil.



196 Where grass and forests cover the soil, water and soil are saved. Where the soil is open to wind and rain, soil and water are lost. Compare the loss in soil and water for the three crops.

Checking Erosion in Ditches and Gullies

As soon as all his sloping fields were planted in grass and clover, Mr. D went to a meeting of his farm neighbors at the schoolhouse. He spoke to the group very earnestly. He said that soil erosion was the problem of the entire community. He suggested that the boys and girls in the school help stop some of the soil erosion by working on the gullies.

Soon the boys and girls, with the help of their teachers and parents, went to work. First, they used loose rock to build dams in the small gullies. The water would be slowed down by these dams so that the gullies would not get larger. Then they planted the big gullies and ditches with kudzu (KOOD-ZOO) vine. This vine spreads rapidly and holds the soil. Like clover and alfalfa, it helps add nitrogen to the soil.

Checking Erosion on Hillsides

The previous owner of Mr. D's farm had used even the hillsides for crops. The rain water had rushed down the unprotected slopes, taking the topsoil with it. On another steep hillside, many gullies had formed. Here the boys and girls helped plant thousands of small evergreens. The covering of needles which falls on the ground under evergreen trees holds the water, and the roots hold the soil.

Contour Plowing

Mr. D had learned a way to plow land for his crops that would help prevent water from rushing down the slope. He did not plow up and down his mild slopes. The up-and-down furrows would have made ditches down which the soil and water could wash. Instead, he plowed across the

slopes, curving his furrows or rows with the *contour* (KON-toor), or curving shape, of the slope (Fig. 197). This is called *contour plowing*. When the plowing is done following the curve or contour, each row or furrow will hold the water or slow it down.

Strip Cropping

Then Mr. D planted these gentle slopes in strips 75 feet wide (Fig. 197). In one strip he planted corn. In the next strip, he planted grass. He might have planted clover, oats, wheat, or soybeans. Because these crops cover the soil, they are called cover crops. In the next strip Mr. D planted more corn. In between strips of cover crops, he might have planted strips of potatoes or tobacco instead of corn.

Corn, tobacco, or potatoes must be cultivated clean; that is, the soil must be kept clear of grass and weeds between rows. During hard rains, this uncovered soil can easily be washed away. With a wide strip of clover or grass crop to hold and cover the soil, soil does not wash down the slope. *Strip cropping*, as it is called, is a good way to check soil erosion and save water for the growing plants.

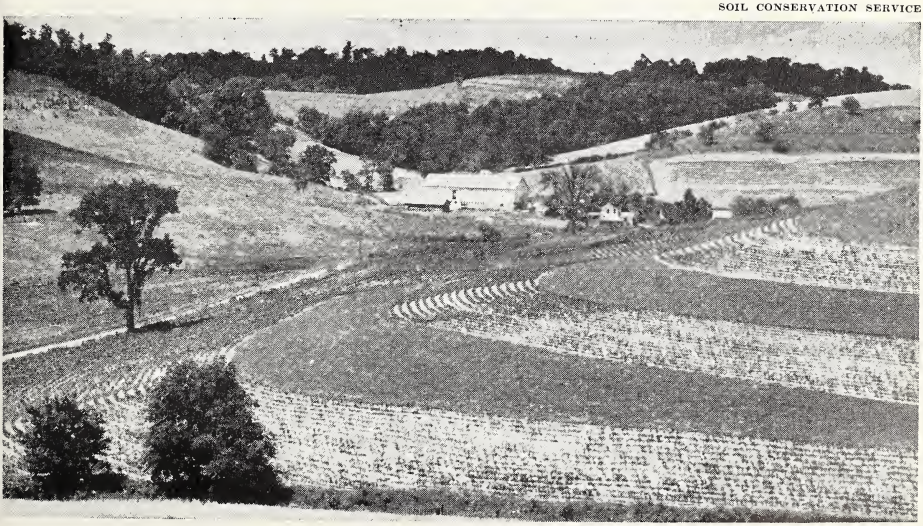
Putting Nitrogen Back Into the Soil

Stopping erosion is not enough. Growing crops each year take certain minerals from the soil. If these minerals are not put back, the plants become poorer and poorer, until at last they are not worth harvesting.

The most important soil loss is nitrogen. Nitrogen compounds dissolve easily and are carried away in water running off the land. Then too, plants use large amounts of nitrogen in their growth. One of the best ways to return nitrogen to the soil is to plant clover, alfalfa, soy-

197 Part of farmer D's farm. Notice the crops in strips planted around the gentle slope. Do you see how water running downhill is caught by each strip — especially by the strips planted with grass or soybeans in between the three strips planted in corn (whitish color)?

SOIL CONSERVATION SERVICE



U.S. DEPT. OF AGRICULTURE

198 See the nodules (tiny balls) on the roots of the soybean. The bacteria in the nodules help add nitrogen to the soil. *Project:* Collect the fresh roots of clover, bean, soybean, or other members of the bean family. Crush the nodules and stain with iodine. Examine the bacteria under the microscope.

beans, or cowpeas — all members of the plant family called *legumes* (LEG-yoomz). Let us look at one of these legumes.

Go out into a field and dig up a clover plant. Shake off the dirt and examine the roots. You will see small *nodules* (NOD-yoolz) or swellings on the roots. Nodules like these are to be found on the roots of all legumes (Fig. 198).

These nodules are full of a special kind of bacteria. These bacteria can take nitrogen from the air and soil to make nitrogen compounds. Then, when the crop of clover or beans or peas is cut, the roots remain in the ground and the soil is enriched with a new supply of nitrogen.

Enriching the Soil with Fertilizers

Plants need other chemicals besides nitrogen. Good farmers find out, by testing their soil, what each field needs, and then supply what is missing by using different kinds of fertilizers. Year after year, some farmers add animal manure to the soil. Manure has in it some of the minerals needed. Many farmers also add commercial fertilizers, mixtures of minerals with phosphates and nitrates in them. The government also provides some chemical fertilizers free or at cost in certain sections where farmers are trying to improve their soils for food growing.

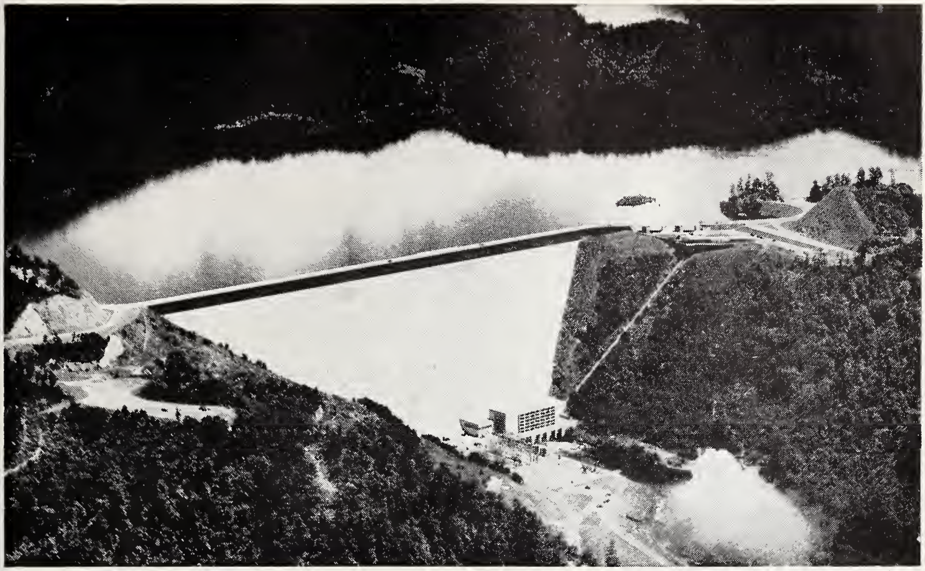
Many farmers have found that in a few years poor soil can be built up if the right methods are used.

Soil Conservation Service

In 1935 the Congress of the United States passed the Soil Conservation Act and set up the Soil Conservation Service. The Service helps farmers in many ways. Scientists in the Service experiment regularly and publish what they have found out about soils. They give advice to farmers and show them how to stop erosion on their farms. They set up model farms where farmers from the community can learn the best ways to save and enrich their soil. The Soil Conservation Service also plans irrigation projects, about which you read earlier.

Large Projects in Soil Conservation

In several parts of our country, the national or state governments have built dams and reservoirs to prevent heavy floods along the rivers



STANDARD OIL CO. (N.J.)

199 Dams like this one near Knoxville, Tenn., control floods — but the water can be used for electric power and, where needed, for irrigation.

In Ohio a number of dams were built a few years ago because each spring great areas were flooded. Since the dams were finished, not once has a flood washed away the topsoil.

Farmers who live in the Tennessee Valley sometimes talk about the time before the TVA, when the Tennessee River used to carry away tons of fertile topsoil. The flooding rivers and poor farming practices had made the land poor, and the poor land had kept the people poor. The Tennessee Valley Authority, a huge conservation project, was set up to improve the region. Its work extended into parts of five states. Dams were built to hold back the rivers. These dams not only prevented floods, but they stored up water that could be turned into water power. This in turn made electricity at low cost for the farmers. Electricity made farm work easier and living more comfortable.

As a part of the project to save the soil and water, the TVA replanted forests. Meetings were set up at which famers talked over the best ways of improving their soil. As a result of the work of TVA, the farms of that section are growing more and better food for the people.

Conservation is Everyone's Problem

As it is now, about 60% of our cropland is turning from bad to worse. Nevertheless, more and more of our farmers and gardeners are learning how to use soil wisely. We need still more men and women who are trained to help teach the methods of soil conservation. Perhaps you would like to make that your lifework.

In order to keep the topsoil on which our food supply depends and make it better, you must know what makes up good soil, how soil may be lost or depleted, and how topsoil can be saved and made better. Study the box on this page to review what you have learned. Put it to use even if you have only a small garden.

Good soil is not everything. Plants and animals can be and are being improved. This means that the food you eat is being improved. Your health and growth are thus made better.

How we can produce more and better plants and animals is the story of the next two chapters.

Good Soil	*Depleted Soil*
1. Good soil, called loam, is a mixture of clay, sand, and humus (parts of decaying plants and animals).	1. Erosion by wind or water depletes soil.
2. Topsoil must be able to hold water long enough for plants to take it in.	2. Minerals in the soil are dissolved and carried away in water.
3. Good soil has substances in it which plants need for growth (nitrogen, phosphorus, calcium, potassium, manganese, iron, and others).	3. Poor crop growing methods (no rotation) take the same kind of minerals from the soil year after year, without replacing them.

Conserving Soil

Some ways of saving topsoil are

1. Contour plowing (plowing across the slope rather than up and down).
2. Strip cropping (growing plants in rows between strips of cover crops).
3. Rotating crops from season to season.
4. Planting legumes to add nitrogen to the soil.
5. Using fertilizers.

LOOKING BACK

Tool Words

In your notebook copy the words in List A. Before the word write the number of the phrase from List B that best explains its meaning. DO NOT MARK THIS BOOK.

List A	*List B*
clay	1. the upper 18 or 20 inches of soil
humus	2. a plant that can put nitrogen into the soil
nitrate	3. an animal which helps put air into the soil
legume	4. soil made up of the very finest of soil particles
nodules	5. remains of decayed plant and animal matter
earthworm	6. a gas that is in air (needed by plants)
contour plowing	7. a method of saving the soil on a hillside
topsoil	8. process by which soil loses minerals
soil depletion	9. a nitrogen compound needed by plants
nitrogen	10. structures on roots of legumes

Test Yourself

To complete the sentences below, select the correct word from the pair of words given and write it in your notebook. DO NOT MARK THIS BOOK.

1. All fertile soils must have in them some (clay, humus).
2. Soil made up largely of very fine dustlike particles is (clay, sand).
3. Soil that has decayed plants and animals mixed with sand and clay is called (humus, loam).
4. Wearing away of topsoil by wind and water is called (erosion, rotation).
5. Making the furrows follow the curves of slopes rather than go up and down the slopes is called (strip cropping, contour plowing).
6. Legumes — clover, peas, beans — have on their roots nodules with (magnesium, nitrogen) in them.

GOING FURTHER

In the Laboratory and Field

1. *Analyzing soil.* Get three samples of soil: rich humus, ordinary garden soil, and a loam soil.

a. Heat a thimbleful of each soil in separate porcelain dishes. An ammonia-like odor indicates the presence of nitrogen. Which soil has the most nitrogen compounds?

b. Shake up a thimbleful of each kind of soil with water. Examine a drop or so under the microscope. Which soil has the most living organisms? Draw pictures of some of these.

c. Repeat the experiment on p. 374 which determines whether soil contains minerals. Plan an experiment to determine the amount of mineral substances in each kind of soil. (*Hint:* Use equal amounts of dry soil by weight.)

2. *Acid and neutral soil.* Take four equal-sized pots of soil. Make a solution by adding the juice of one lemon (which contains citric acid) to a glass of water. Add this solution to the soil in all the pots until the water dripping from the holes at the bottom is acid to litmus paper (blue litmus turns red in acid). Now mix enough agricultural lime (limestone) into the soil of two pots to turn the litmus neutral. Plant corn seeds, in the acid soil of one pot and in

the neutral soil of another. Plant beans in the other two pots. Allow the plants to grow in a sunny spot. Keep careful notes. What are your conclusions?

3. *Soil minutemen.* If you live in a farm area, take a field trip to survey good and bad farm practices. Organize a club of "Soil Minutemen" to help fight erosion.

4. *A model farm.* Make a model farm which shows good farm practices. You can use bits of sponge colored green for trees in forests, and pebbles glued on cardboard for stone walls. Your teacher will give you more help if you need it.

Put on Your Thinking Cap

In the Missouri Valley, farmers are discussing the value of building dams and controlling rivers. Some are against it. They say it costs too much and does not do much for the soil. Some are for it. They say it will save money in the long run and make the soil grow more crops. What evidence could you give on either side?

Adding to Your Library

1. *Soil Savers* by C. B. Colby, Coward, 1957. Excellent photographs show the work of the Soil Conservation Service of the United States Department of Agriculture.

2. *Down the River.* The story of Soil Conservation. Soil Conservation Society of America, 1016 Paramount Building, Des Moines, Iowa.

3. *Rocks and Rain and the Rays of the Sun* by William Fox, Walck, New York, 1958. Mr. Fox is a conservation specialist with the U.S. Soil Conservation Service. This little book is easy to read and interesting.

4. *How to Make Earthworms Pay* by Tom Parsons, Abelard, New York, 1958. This tells you about how earthworms help the soil.

5. *Conservation* by David Cushman Coyle, Rutgers University Press, 1957.

A Bit of Research

Find out all you can about the organization known as Friends of the Land, which has branches in nearly every state of the Union.

Careers for You

Farmers are needed to use the newer methods of saving and improving the soil. *Farm Bureau agents* test soils and help farmers by showing them how to lay out the patterns for contour plowing. They advise farmers how to improve the soil and prevent erosion.

Soil conservation agents are experts in the branches of service that deal with soils, and can show farmers how to save their soil as well as build up soil that has become depleted.

Think also about the life of a *forest ranger*. Or perhaps you are interested in having a tree nursery. *Nurserymen* are in demand by lumber companies, as well as the Forest Service of the United States.

CHAPTER 20

Production Through Reproduction

A female goat and her two young kids. Throughout this country — on every farm — parent animals or plants are producing young. This production through reproduction is important to all of you.

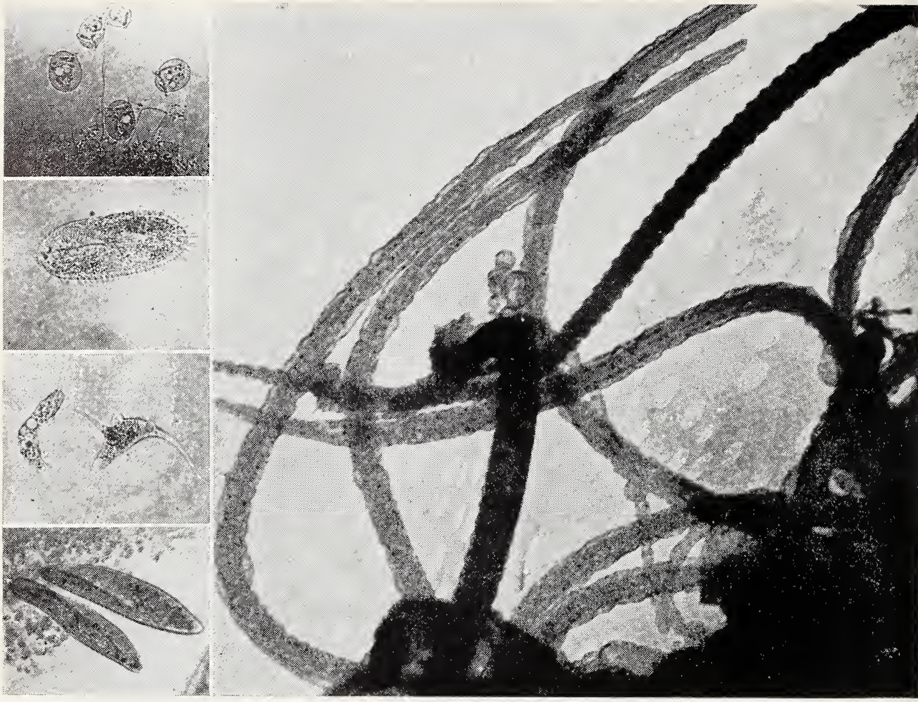
WHAT do you see in the picture above? A goat with twin kids. Have you any idea why this picture is here? It is evidence of an important fact. Usually goats give birth to only one kid. Now scientists are trying to develop a strain of goats and sheep which produce twins. That is, they are trying to double the production of goats and sheep.

The farmer of today knows he must make his plants produce not only more plants and animals than ever before but better plants and animals as well. His problem is a double one:

1. To increase production of plants and animals that we want.

2. To keep harmful plants and animals from producing more of the same kind.

In order to understand how this double problem can be solved, we must first know something about how living things *reproduce*. That is, how do living things make new plants and animals? How do the young grow and become like their parents?



LEFT, TOP TO BOTTOM: HUGH SPENCER, BAUSCH & LOMB OPTICAL CO., HUGH SPENCER, DU PONT "BETTER LIVING"; RIGHT: R.C.A.

200 Seen under the microscope. *Left from top to bottom*, vorticella, the bell protozoon; a rare green paramecium; an ameba; the common paramecium. *Right*, the hairlike cilia, greatly magnified, of an animal like the one second from the top. These are viewed under the high-powered electron microscope.

Old Beliefs About Reproduction

You have read about the experiments of Francesco Redi in the first unit of this book. He proved that flies produce flies. Redi and other early scientists introduced the idea that probably only living things can produce living things.

In spite of experiments that Redi and others made, people still asked, "Do all living things come from other living things?" Many persons thought that food and water could produce germs and other microscopic plants and animals.

A great Italian scientist, Lazaro Spallanzani (LAH-zah-roh·spah-lahn-TSAH-nee), planned some experiments to find out whether or not these tiny one-celled living things could be reproduced from nonliving water and soup. In one of his experiments Spallanzani studied some tiny *protozoa* swimming in a drop of water under his microscope lenses. A protozoon is a one-celled, microscopic animal often found in pond water. Next to the first drop of water he placed a drop of pond water that had been boiled long enough to kill all living things.

Under the microscope, Spallanzani carefully joined the two drops of water so that they were connected

by a thin bridge of water. Then he saw one protozoon swim into the drop of pure water. He wiped away the bridge between the two drops. Now the protozoon was left alone in the drop of boiled pond water.

He kept on watching the one-celled animal, and what did he see? Just what you, too, can see under your own microscope. He saw the tiny animal divide into two animals. The protozoon had produced another protozoon. Again, Spallanzani had proved that even microscopic living things come from living things, not from any kind of dead or nonliving material. Scientists since the time of Spallanzani have given other proof that plants and animals reproduce their own kind.

Now you will want to see through your microscope some of the same things Spallanzani saw.

REPRODUCTION BY ONE PARENT

Go to a pond or stream either in the late spring, summer, or autumn and fill several jars with water. Add a little mud from the stream and also some of the water weeds you find in the water. When you get home, add about 20 rice grains or 15 wheat grains to the water in the jars. Set these jars aside where it is neither too hot nor too cold (about 65° F.). In a week or so, if you look carefully, you will see tiny white specks swimming about. These are probably the one-celled animals, protozoa. Probably the one you will see will be the *Paramecium* (pair-uh-MEE-see-um) (Fig. 201). Possibly you will see other microscopic animals, such as those in Fig. 200. Study this figure carefully when you look through your microscope. You will be able to recognize some of these animals.

If you examine some of these single-celled animals under the microscope, you may see one divide. It begins to pinch together in the middle. In a little while it divides in two, forming two animals from one. Paramecia which have plenty of smaller living things to feed upon can reproduce by dividing as often as once every 18 to 24 hours.

There is an important thing to learn from this observation. As you might expect, each daughter paramecium looks like the other, because the two came from one parent. This type of reproduction, in which there is only one parent, is called *asexual*

201 One paramecium, well fed, begins to divide. Soon there are two. *Project:* Fill a small jar one-half full of pond water. Add 5 rice grains. Let it stand. In two weeks examine under a microscope for paramecia or other protozoa.

(ay-SEK-shoo-ul) *reproduction.* That is, two animals are produced from one.

Why do the two daughter cells have to look alike? Scientists have found the reason. If you were to stain a paramecium with a special kind of dye, you could see a dark oval structure in its center. You can see this structure in the left-hand drawing in Fig. 201. It is called the *nucleus.* As you remember, almost every cell has a nucleus. Every one-celled animal has a nucleus. When the cell divides, the nucleus divides into two equal parts. Each cell then has an equal amount of the nuclear material responsible for the appearance of the cell. Scientists have found that this material in the nucleus makes any plant or animal look the way it does. You can now answer this question: When the paramecium divides, why are the two cells which are produced just alike?

Gardeners and farmers often use asexual reproduction to get more plants from a single parent. Let us see why and how it is used.

Making Sure We Get the Same Kind

Would you like to experiment with growing plants by asexual reproduction? You can set up experiments at school or at home. There are several ways to make plants reproduce their own kind. Let us try a *cutting* first. You will need a pot of moist sand.

Take a geranium plant and cut from it a stem about three inches long. First, remove most of the leaves of the cutting. The leaves are cut off because the plant does not yet have roots to supply so many leaves with water (Fig. 202). Stick the cut end of the stem into the pot of sand. If you take good care of the cutting, in a few weeks it will be a complete plant with new leaves and new roots. It is now ready to be transplanted to another pot with about one part of sand and three parts of good garden soil. Because you took a cutting of part of the old geranium, the new geranium will look very much like the old one. It will have flowers of the same color as the parent plant.

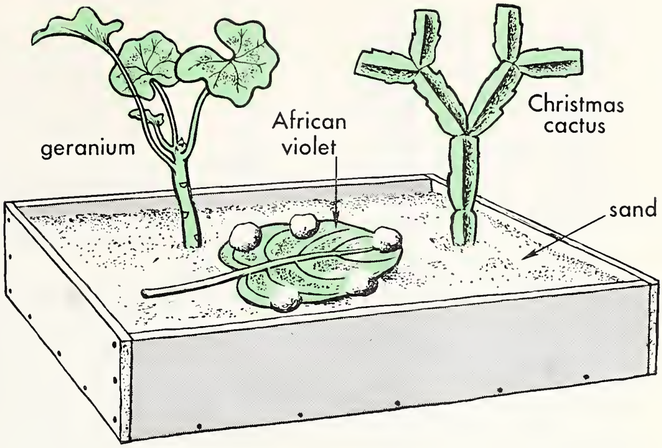
You may wish to try to grow other plants by asexual reproduction. Try planting cuttings of forsythia, willow, or begonia plants.

Plants can be grown from leaf cuttings of stems or leaves. Many persons start certain plants by keeping a leaf and its stem in moist sand until roots have started. Try starting a leaf from an African violet plant in moist sand. When you put the plant into a pot, be sure the pot is not too large for the little cutting.

You may also grow entire plants from their fleshy roots or fleshy stems. Place a carrot, a beet, or a sweet potato (all fleshy roots) in moist sand. Soon these parts of plants will produce a new plant of the same kind as the parent plant.

The farmer depends upon asexual reproduction for his crop of potatoes. White potatoes, which are actually thick underground stems, are cut up into pieces, each of which has an "eye" or bud. When these pieces are planted, they will produce potato plants. To be sure that he has potatoes that are of a certain kind, the farmer plants "seed potatoes" that have been saved from the crop of the year before. He can depend upon these potatoes to produce potatoes of the *same kind.* If he planted true seeds

202 *Project:* Fill a box like this one with moist sand. Then try to grow plants like these from cuttings. Or try begonia stems or willow twigs. (Be sure the sand has been washed.)



formed from the flowers of potato plants, he could not be sure of getting the same kind of potatoes as those from which the seeds came. You will see why later in this chapter.

More Examples of Asexual Reproduction

A trip through a farm will show you many ways in which the farmer uses asexual reproduction to make his plants reproduce for him. In the strawberry bed, notice how each strawberry plant sends out runners. These runners are long stems that grow along the ground. At certain points on these stems, a new plant will form (Fig. 203).

The underground parts of many plants, such as rhubarb, peonies, day lilies, or dahlias, can be broken into several parts. Each part will produce a new plant of the same kind as the parent.

Have you ever seen a rambler rose? You can easily get more ramblers by a method of asexual reproduction known as *layering*. Bend one of the long stems of the rose till it touches the earth. Where it touches, cover it with soil. Next spring a new rose plant will grow from the point where the old stem was buried.

The Fruit Grower Uses Asexual Reproduction

No doubt you have heard about *grafting* fruit trees. Do you know how it is done? In the fall, let us watch the farmer prepare some apple trees for planting. On his bench are a sharp knife, some soft wax, and some raffia (RAF-ee-uh) or twine. He has some crab-apple seedlings (young plants) and some Baldwin apple twigs in a box of cool, moist sand. He is going to join or *graft* the Baldwin twig to the crab-apple seedlings.

203 New strawberry plants grow from runners like the ones you see on the right.

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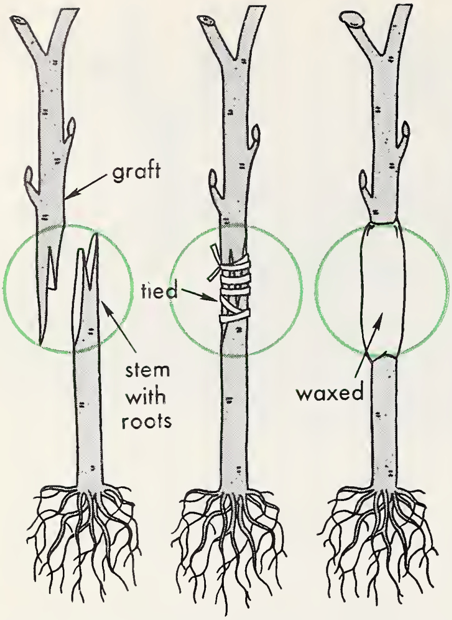


204 To make a graft, follow the steps shown. Try it on a twig of a fruit tree.

Study Fig. 204 before you read how the farmer makes his grafts. He takes a crab-apple seedling with roots at one end, cuts off the top and makes a notch or cleft in the stem. Next he takes a Baldwin apple twig and cuts a "tongue" in it. He fits the Baldwin twig into the crab-apple stem (Fig. 204). Then he winds raffia tightly about the place where the two twigs are joined and covers it with grafting wax. Now his little tree has the roots of a crab-apple tree and the stem and leaves of a Baldwin. Believe it or not, the tree will bear Baldwin apples only.

Why doesn't the farmer plant a cutting from a Baldwin tree? The best reason is that cuttings of Baldwin apple trees do not take root easily. Why not plant a Baldwin apple seed? The answer is that seed from a Baldwin apple tree may not produce a Baldwin apple tree. We shall need to study how seeds are formed in order to see how this may happen.

REPRODUCTION BY TWO PARENT PLANTS

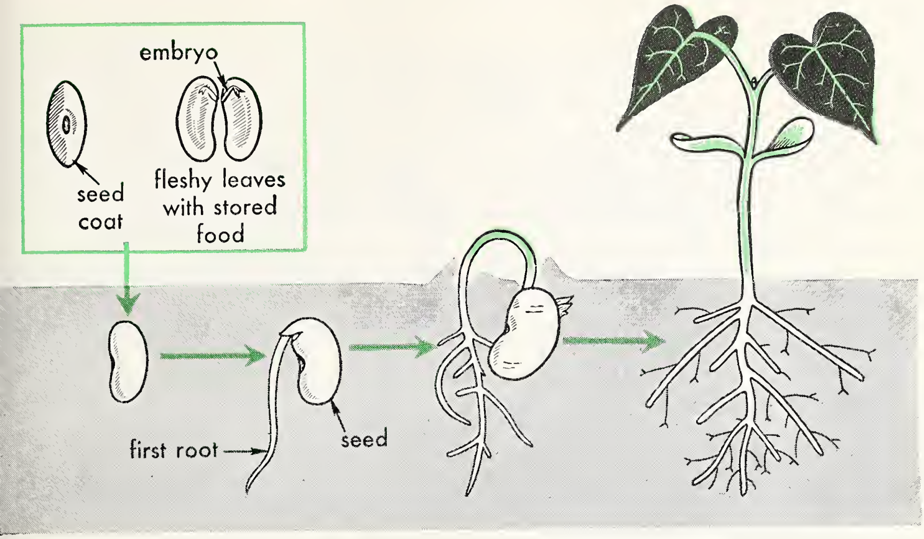
We usually think of planting seeds when we want to grow new plants. You know now that planting seeds is only one way to get new plants. What is in a seed that enables it to produce a new plant? Let us open a large seed and examine it, to find out.

Soak a handful of bean seeds in water overnight. In the morning peel the seed coat from one of them. The seed coat keeps the seed from drying out (Fig. 205). Now divide the two halves of the seed. Each half is a leaf, in which there is stored food for the young plant. Between these two leaves, you will find the young plant, called the *embryo* (EM-bree-oh) (Fig. 205). Can you see the embryo's small leaves and its little root? Examine these with a magnifying glass.

Plant the other soaked bean seeds in moist sand or sawdust. Every three days dig one out and make a drawing of it. Date your drawings. Do your notebook drawings look like those in Fig. 205?

From this work you can see that a seed is an embryo plant with its stored food, protected by a seed coat.

Since people eat the food stored in such seeds as peas and beans, and in such fruits as berries, apples, and tomatoes, the farmer wants to improve his production of seeds and fruits. Much of his time in the sum-



205 Beans develop as shown above. *Project:* Soak other kinds of seeds in water overnight. Then pull them apart and see if you can find embryos and fleshy leaves (with stored food) in them. Plant some of the seeds and compare their development with that of the bean.

mer is spent killing weeds and fighting the insects that harm plants and cut down production. You will read more about plant enemies later.

No Flowers — No Seeds

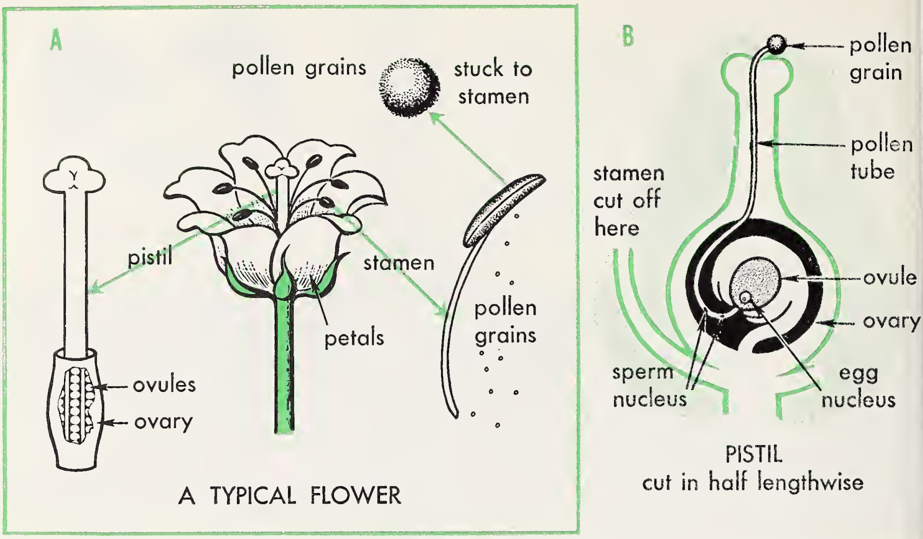
Before you read this section, look carefully at several flowers and compare them with the diagrams in Fig. 206. Perhaps you can find the flower of a lily to examine.

If you push the petals of a lily apart, you will find six long slender pinlike structures with a tiny knob on top. These are *stamens* (STAY-menz). The top of the stamen may be dusty with yellowish *pollen* (POLL-en) *grains*. If you put one of these pollen grains under the microscope you will find that it looks like those in Fig. 206A.

Now examine the thick central structure of the flower. This is the *pistil*. The top part of the pistil is sticky. Therefore, it can catch and hold the grains of pollen. The large bottom part of the pistil is the *ovary* (OH-ver-ee). It holds small oval-shaped bodies that will form into seeds. These beginnings of seeds are called *ovules* (OH-vyoolz).

The lily has six stamens and a pistil. When you examine other flowers you will find different numbers of stamens. The four o'clock has from three to five; violets have five, and buttercups have many stamens.

Some plants, like the willow and the cottonwood (Carolina poplar) have flowers with stamens on one tree and flowers with pistils on another. Can you find staminate and



206 In B, follow the pollen tube into the ovary. When will a seed be formed? *Project:* With the microscope, study the different kinds of pollen grains of different flowers. Also cut open the ovaries and examine the differently shaped ovules.

pistillate flowers of the poplar tree? The staminate flowers will have pollen grains at the tip of each tiny stamen. The pistillate flowers will have a tiny ovary in which the seed will develop (Fig. 207).

Stamens and pistils are the most important parts of a flower. Without them no seed would be produced. Let us now see the way in which seeds are formed.

Fertilization

Seeds cannot be formed unless the pollen grains unite with the ovules. What is in the pollen grain and ovule that is responsible for making the seed?

Scientists have found that both pollen grains and ovules are special kinds of cells, each having nuclei. In the pollen, we find male or *sperm* nuclei; in the ovules, female or *egg* nuclei. Before a seed can be formed, a sperm nucleus must unite with an egg nucleus (Fig. 206B). But the pollen falls on the sticky pistil. How does the sperm nucleus get down from the pollen grain on the sticky pistil to the egg nucleus in the ovule?

If the stamens and pistil are in the same flower, the pollen grains can be knocked off the stamen onto the sticky pistil by the least movement of the flower. In other plants, the wind or insects carry pollen from one flower to another. After the pollen reaches the pistil, each pollen grain grows a long pollen tube. This tube carries the sperm nucleus to the egg nucleus in the ovule. When the tube reaches the ovule, the egg and sperm unite. This union of the egg and sperm is called *fertilization.* As soon as the egg is fertilized, it begins to develop into a seed.

The farmer will not get seed and

fruits from his plants or trees unless the flowers are *pollinated* (POLL-ih-nayt-ed). The pollen must reach the pistil and then the ovule. Then fertilization takes place, and the seed begins to form.

For most crops the farmer need not worry about pollination. Wheat and oats are self-pollinated; that is, the plant's own pollen falls on its pistil. Examine a head of wheat or oats to see how this could happen. The wind may help the pollination of corn by carrying the pollen from the tassels to the silks. The tassels are the stamens; the silks are the pistils. Because the tassel is above the silks, the pollen usually falls on the silk.

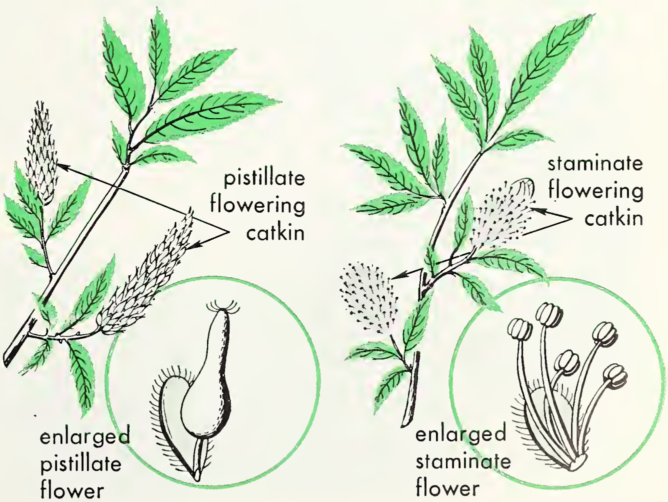
Cross-Pollination

Suppose, however, that the farmer wishes to grow crops that are not self-pollinated. Do you see his problem?

To pollinate his fruit trees, his cucumbers, his buckwheat, and his clover plants, the farmer needs the help of bees. Many farmers keep hives of honeybees for this reason. Bumblebees help, too, especially with the pollination of clover. The bees take some of the nectar and pollen in the flower for food. As they fly, they often carry the pollen of one flower to the pistil of another. When the pollen is brought from a different flower, *cross-pollination* takes place.

You will want to read more about the work of bees. On p. 406 are listed some books with more information than we have space for here. Without bees many of our food products could not be grown.

Now you can see why farmers prefer to get their young fruit trees by grafting rather than by planting seeds. Fruit trees are cross-pollinated. The ovule in a Baldwin apple may have been fertilized by pollen brought from a Greening apple tree. A new tree grown from the seed would be a cross between the Baldwin and the Greening. If the farmer were experimenting to get new kinds of apple trees, he would plant seeds, but if he wanted to be sure of the kind of tree, he would use grafting.

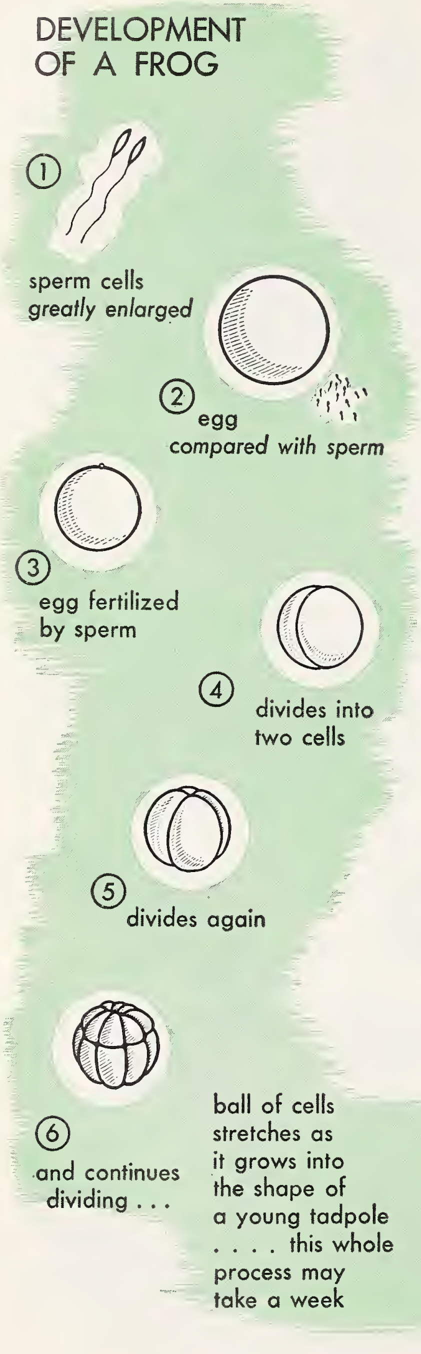


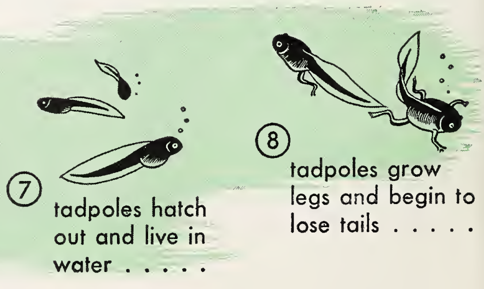
207 Two kinds of flowers of the willow — the female flowers at the left; the male flowers at the right. Which will have the pollen? Which the ovules? (A catkin is a group of flowers found in willows, poplars, birches, and other trees.)

Reproduction by One Parent or Two

In growing plants from cuttings and grafts, only one parent plant is used. This process, as you have read, is called asexual reproduction. When seeds are produced, two parents are needed. Reproduction by two parents is known as *sexual* reproduction, because two sexes are united. The male parent produces sperm (found in the pollen tube), which unites with the egg (found in the ovule) of the female parent.

There is an important difference between the offspring from just one parent (asexual reproduction) and the offspring of two parents (sexual reproduction). With one parent, there is only one kind of nucleus to make the offspring what they are. We can therefore be sure that they will all be the same as the parent. With two parents, there may be two different kinds of nuclei. For example, if a male nucleus from a McIntosh apple tree unites with the female nucleus





208 The development of a frog. *Project:* In the spring collect fertilized frogs' eggs. (Fertilized eggs have the black side floating up, unfertilized with the whitish part up.) Watch them develop. Feed the tadpoles lettuce and bits of cooked liver.

of a Northern Spy apple tree, the young tree may be like both in some ways.

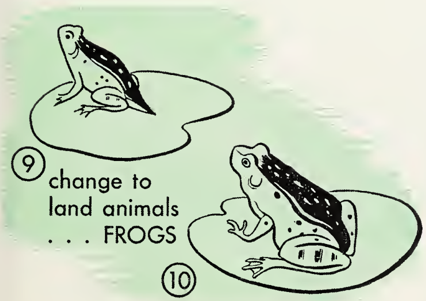
In the asexual reproduction of a Northern Spy tree, 50 of its twigs could be grafted, and the fruit grower would be sure that the new trees would be Spy trees. If he planted 50 seeds from the Spy tree, many of the young trees would be different. They might be like either parent or like both of them in some ways.

REPRODUCTION BY TWO PARENT ANIMALS

You probably know that most animals have two parents. Chickens, sheep, and horses are common examples. So is a frog (Fig. 208).

Animal Reproduction — The Frog

In the early spring, search for frogs' eggs in the small ponds and streams. They will be in a jelly-like mass. Probably the eggs will already have been fertilized; that is, a sperm from the male frog will have united with each egg from the female frog. Union of sperm and egg produces a fertilized egg. Under the right conditions it will develop into a frog.



Sperm cells are so small that they can be seen only under the microscope (Fig. 208). By moving their tails they swim rapidly until they enter an egg, which is many times larger. The frog egg is surrounded by jelly. It is also filled with whitish yolk, which will be the food of the frog embryo as it develops.

You will find it interesting to watch a frog's egg develop. With a hand lens, you will be able to see that the fertilized egg is a ball of cells. In about a week this ball of cells develops into the shape of a young tadpole.

The tadpole hatches out of the jelly and begins to feed on water weeds. It is a water animal breathing by means of its gills. As time goes on, the tadpole begins to lose its tail, and its legs appear. At the same time lungs for breathing on land are developing. Thus a water animal, a tadpole, changes into a land animal, a frog. The frog must live in a moist environment, because it breathes through its skin as well as with its lungs.

All *amphibian* (am-FIB-ee-un), or land-and-water, animals develop in much the same way. Toads, salamanders, and newts are amphibians.

Breeding Birds and Mammals

Farmers breed chickens, turkeys, and geese for market. The poultry farmer usually keeps a pure line of stock; that is, he may have only Plymouth Rock hens and roosters or only White Leghorns. This is important to the farmer if he produces poultry and eggs for market. Certain breeds are better for eating, and others better for egg production. If

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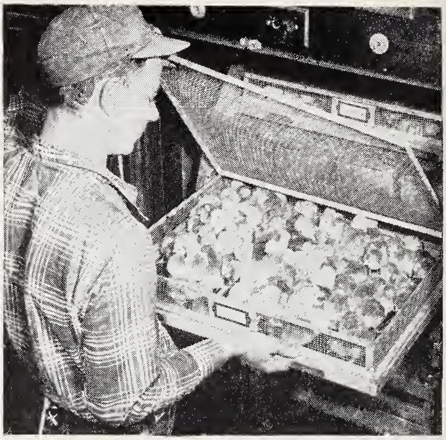


NORTH CAROLINA STATE COLLEGE

209 Believe it or not, you are looking at a good substitute for the mother hen. The eggs (*left*) are placed in the incubator (where the temperature is kept at about 103° F). Twenty-one days later — a tray full of chicks (right).

two parents are of the same breed, the chicks will be like their parents.

You may wish to watch fertilized hens' eggs develop into chicks in the classroom. Buy about a dozen fertilized eggs at a chicken farm. The eggs will need warmth to develop. Have you seen hens sitting on eggs to keep them warm? On many farms, eggs are kept in an incubator, which is built to hold the eggs and keep them warm while the chicks are developing. In this way, several dozen eggs can be cared for at the same time (Fig. 209). In the classroom, you may also use an incubator.

To start your incubator, put a pan of water in it to keep the air moist. Keep the temperature at 104° F.

As soon as you bring your eggs to the classroom, open one of them. The shell keeps the eggs from drying out. On the yolk you can see a whitish spot. This is where the embryo will begin to develop. The egg white and the yolk serve as food for the embryo as it develops.

Because the tiny sperm could not possibly get through the hard egg shell, the union of the egg and sperm takes place in the body of the hen before the shell is formed.

Place the eggs in the incubator. Be sure to turn them over each day to help the embryo develop evenly.

Every day or two take an egg from the incubator, open it carefully, put it into a watch glass and cover it. You will be able to see the tiny heart beating. At five days it will look like Fig. 210. On the twenty-first day the chick will peck its way out of the shell.

Do not feed the young chick at

first. It has enough stored food from the egg yolk to last for 48 hours. Keep it warm, and in two days it will be an active little chick, ready to feed itself.

Not all birds are like the chick that is born almost ready to feed itself. Some, like the robin, are born helpless and without feathers, in a nest high above the ground. They depend upon their parents to bring them food.

Mammals on the Farm

The mammals on the farm — the cattle, pigs, sheep, goats, and horses — are even better protected during their development than are the birds. A developing chick is protected only by its shell. But most mammals are fertilized and develop inside the body of the mother. They are born alive, and after birth the mother cares for them and protects them.

All mammals feed their young milk from their milk (mammary) glands. No other animal group feeds in this way.

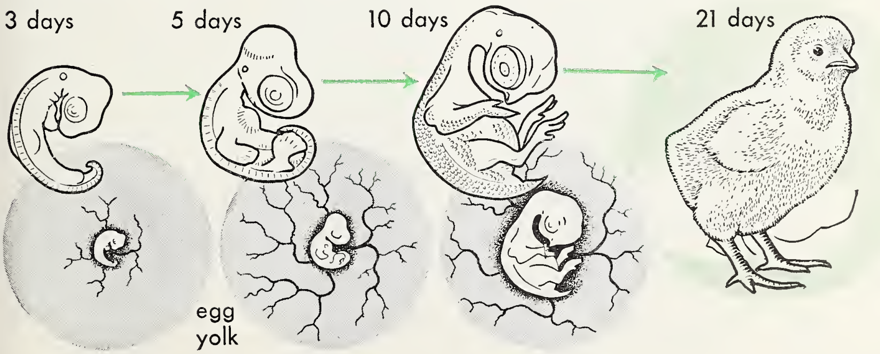
The farmer is kept very busy providing food for the mammals on his farm. The mother animal must have plenty of food not only for herself but also to provide milk for her baby. When it is old enough, the young mammal can be turned out to pasture or given prepared food.

Most farmers or ranchers raise only one breed of cattle or hogs or sheep. Since the male and female are of the same breed, the farmer or rancher can be sure that the young will be like its parents. He keeps only the strongest and best of his animals for breeding. Thus he is always working to improve animal production and the food supply for the market. However, he does not depend only on the same kinds of plants and animals. He tries to develop new and better types. Let us see how.

NEW FORMS FROM OLD

You must have been to a movie recently in which you saw a western cattle ranch. Did you see any longhorn cattle? Probably not. Longhorn cattle, as you can see from Fig. 211, are dangerous animals. These animals would be hard to handle. When

210 Four "stages" in the development of a chick from a fertilized egg. If you do the experiment described on the opposite page, you will find some stages not shown below. *Project:* Make drawings to show the "stages" you see if you do the experiment.



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211 Above, a longhorn. Scientists have bred heavier, much safer hornless animals like the shorthorn below.

shipped to market in boxcars, they would fight and gore each other. You can see that a breed of shorthorns would be better to raise than longhorns. As it happens, shorthorn cattle are heavier; they have more beef. How would you go about developing such a breed?

Are Acquired Traits Inherited?

Possibly you would decide to cut off the horns and mate two animals whose horns you had cut off. Any cattleman would tell you that it would not work. They used to cut off the horns of longhorn cattle to make them less dangerous to handle. Yet the offspring of these cattle always developed long horns.

Cattlemen know that the trait of growing long horns is inherited. In human beings, eye and hair color, shape of face, nose, ears, and height are among the traits we inherit. Scientists call any physical trait which is not inherited an *acquired trait*. If hair is dyed, for instance, the new color is an acquired trait.

August Weismann (VYSS-mahn), a scientist, wondered whether acquired characteristics could be inherited. He wanted proof. In the late nineteenth century he began working to find out. He took some young mice and cut off their tails. When they became adult mice, he mated them. Would the offspring have tails or not? They all had tails. He cut off the tails again. He mated this second generation, but again the offspring were born with tails. Weismann did this for many generations of mice, until he was sure that having a tail was an *inherited trait*. He concluded from his experiments that acquired traits cannot be inherited (Fig. 212).

We see now why the hornlessness gained by cutting off the horns of cattle is an acquired trait. It cannot be passed on to the offspring.

Applying These Facts to Yourself

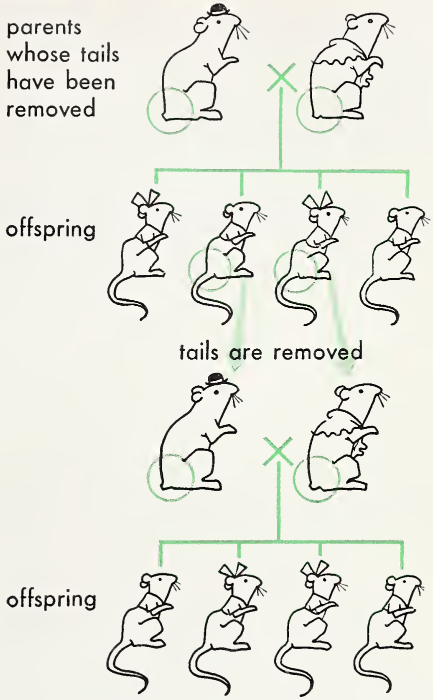
No doubt you have heard the saying, "Like father, like son." This is a short way of saying that a son inherits his father's traits. Is this true?

You can see that physical features, such as eye and hair color, shape of face, and size and shape of body, are inherited from both parents. But does the child inherit his parents' behavior? For instance, does he inherit their hatreds, their likes and dislikes, their prejudices?

If you think a moment you will know that such things are learned, not inherited. They are acquired traits and are taught to children by their family and friends, by their teachers, the radio, the television, and the movies. These acquired traits cannot be passed on by inheritance; each generation must learn them for themselves. A man's knowledge of mathematics or music or science is acquired. His children, therefore, must go through the work of learning mathematics, science, or music.

What then can be inherited? Scientists today believe that the only traits that can be passed on to the offspring are those that are present in the nuclei of sperms and eggs of the parents.

Then is it hopeless for cattlemen to try to breed shorthorned cattle? Let us go on.



212 Weismann's experiment. Parent animals with tails removed always produced young with tails. What happened in the second generation? Are acquired characteristics inherited?

Mutants

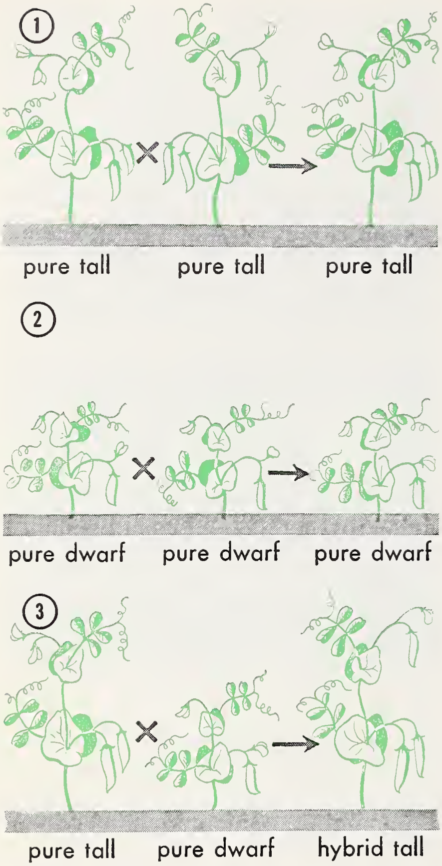
How can we get a breed of cattle with short horns if we cannot get rid of the long horns by cutting them off? The answer is that we must wait for an *accident in inheritance.*

Have you ever seen a white crow or a white robin? They are called *albinos* (al-BY-nohz). They are an accident in heredity. Such accidents are very rare, but they do happen. Breeders call such accidents *sports*, but scientists call them *mutants* (MYOO-tants). *Mutant* means something that has changed. When a change or *mutation* occurs, some of the contents of the nucleus of a sperm or egg has been changed. This change produces the new trait. Scientists do not know yet how such changes happen.

How can you test whether a new trait is a *mutation* or an *acquired trait?* You can find out by breeding the animal for several generations. If the trait reappears many times during constant breeding, it is a true mutation.

The white rat which you sometimes have in the school laboratory is a mutant. It first appeared in the offspring of two gray rats. When it was mated to another white rat, more white rats were produced. White fur was, therefore, a mutation, not an acquired trait.

Now let us go back to the problem of the longhorns. Scientists have discovered that the contents of the sperms and eggs are responsible for



213 Tall is dominant over dwarf. *Top*, tall × tall (pure) = tall. *Middle*, dwarf × dwarf (pure) = dwarf. *Bottom*, tall (pure) × dwarf (pure) = tall — tall, not dwarf; therefore tall is dominant.

such traits as long horns. By now you have probably guessed that a mutant shorthorn was found in a herd of longhorns. The breeder who wanted to get more shorthorns followed these principles of breeding:

1. He selected the trait he wanted. In this case, it was short horns. His shorthorned animal was a mutant.

2. He mated his shorthorned animal with a longhorned animal. Some of the offspring born had the trait for short horns.

3. Then he mated only shorthorned animals. This inbreeding produced only shorthorned animals.

Because of such experiments, longhorned cattle are rapidly being replaced with the more desirable shorthorned breeds.

What Characteristics Can Be Inherited?

In a monastery in Austria in 1850, a monk was experimenting with pea plants. He was trying to find out what traits could be inherited. The experiments of this Austrian monk, Gregor Mendel (MEN-del) (Fig. 216), are today the basis of all that scientists know about the passing on of traits from parents to children.

For two years Mendel had worked to produce a pure line of tall pea plants and another pure line of dwarf pea plants. What is a *pure line?* Whenever Mendel mated two pure tall plants, the offspring were always tall (Fig. 213). Since the offspring were always tall, the parent plants must have been pure-line tall plants. He did the same thing with his dwarf plants. When he mated two pure dwarf plants, the offspring were always dwarf.

A pure line always produces in the offspring the one trait for which the parents were bred. Tallness was in the nuclei of the tall plants; dwarfness was in the nuclei of the dwarf.

The next step in Mendel's experiments was to mate a pure-line tall pea plant with a pure-line dwarf plant. What do you think happened? The result was very puzzling: all the

CORN—A SEED PLANT

Green plants are the only living things that can make food from air, water, and sunlight. The next pages show the main structures of a corn plant and how it makes food.

Photo by Maertens from FPG.
All artwork by CARU Studios, Inc., New York City. Plant Charts 1 and 2 adapted by permission from EXPLORING BIOLOGY: Fifth Edition by Ella Thea Smith. Photomicrographs by General Biological Supply House, Inc., Chicago, Illinois; Carolina Biological Supply Company, Elon College, North Carolina.

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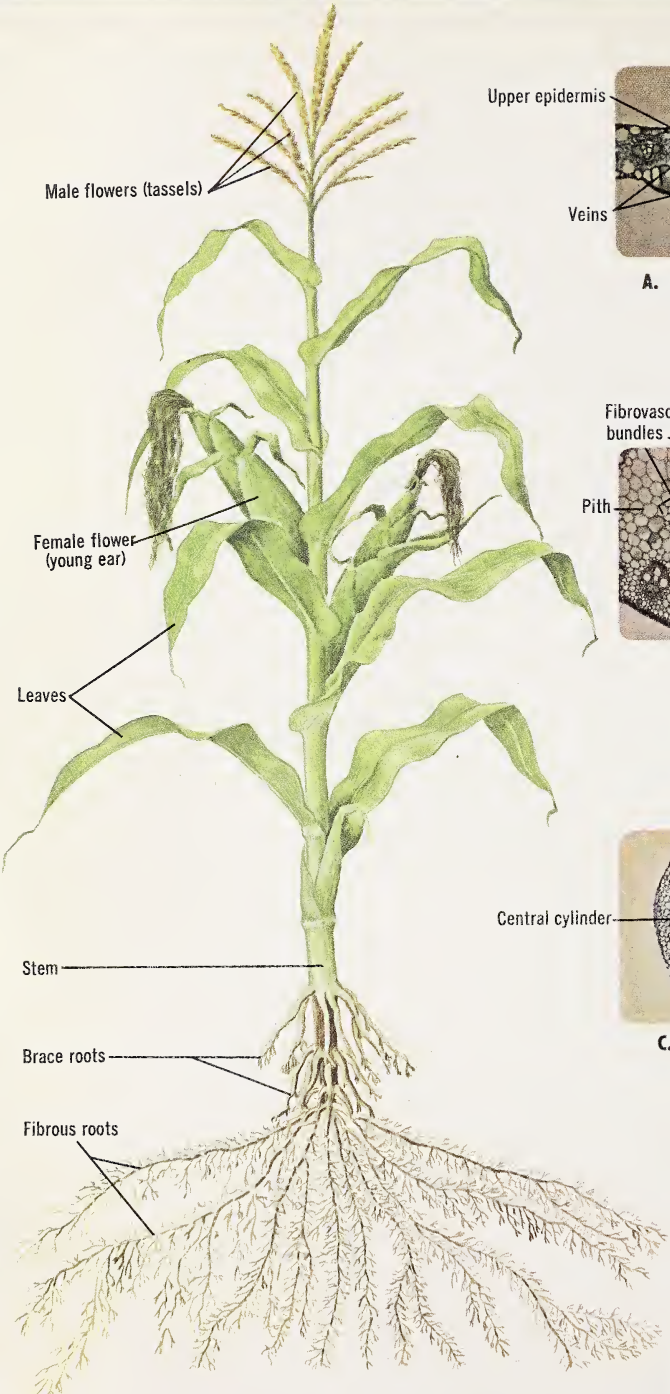
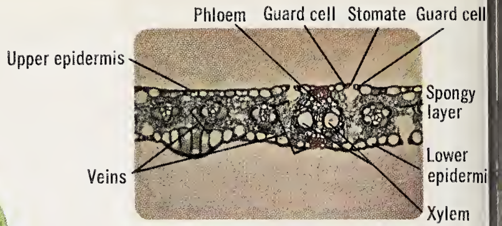
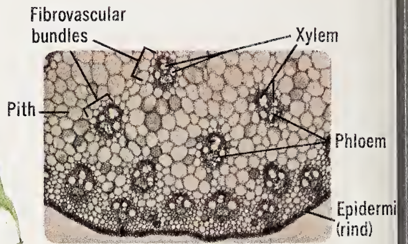
PLANT CHART 1—THE GROWING PLANT

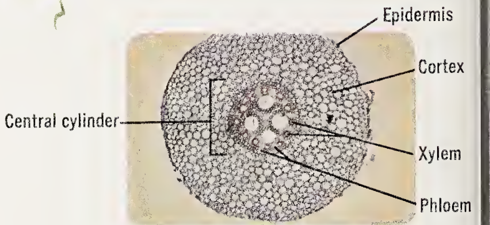




A. The Leaf in Cross Section
(much enlarged)



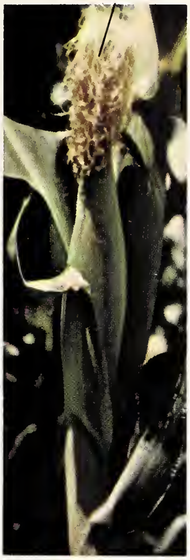
B. The Stem
(much enlarged)



C. A Fibrovascular Bundle
(much enlarged)

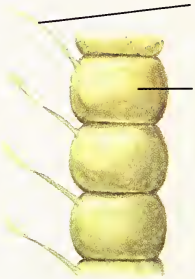
(Photomicrographs of leaf and stem copyrighted by General Biological Supply House, Inc., Chicago, Illinois; photomicrograph of root, Carolina Biological Supply Company, Elon College, North Carolina)

D. Stamens on a Tassel (much enlarged)

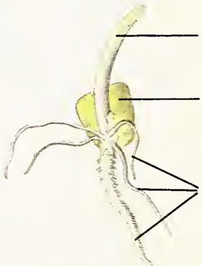


E. Female Flower (young ear)

F. Pollen on Silks (enlarged)



G. Ovaries, with Silks

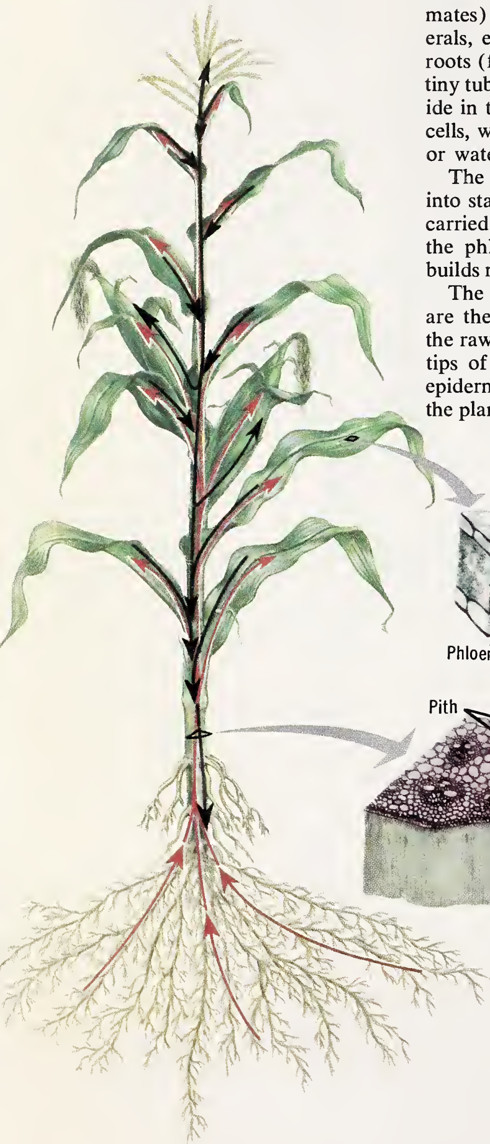


H. Seedling

THE GROWING PLANT A corn plant, like other green plants, has four main organs—roots, stem, leaves, and flowers. The roots anchor the plant to the ground, the stem gives support, the leaves contain the plant's food factory, and the flowers make seeds for new plants.

Notice the xylem and phloem tissues in *A*, *B*, and *C*. These are the plant's circulatory system, through which water and minerals taken in by the roots and food made in the leaves move to all parts of the plant. Together, these tissues make up the fibrovascular bundles *(B)*. These and other tissues in leaves, stem, and roots are similar to those in other seed plants. A corn plant has parallel veins in its leaves, one seed leaf in the seed, and other features which make it different from plants with a network of veins in their leaves and two seed leaves in the seed. Plants like corn with one seed leaf (monocotyledon) are called monocots; plants having two seed leaves (dicotyledons), like a geranium (with netted veins), are called dicots.

NEW PLANTS The flowers are the corn plant's reproductive system. The tassels are the male flowers *(D)*, and the young ears *(E)* are the female flowers. The tassels produce pollen which is blown by wind to the silks *(F)* of the female flower on the same or another plant. Pollen tubes grow through the length of the silks, and fertilization takes place; the ovaries then mature into ripe kernels of corn *(G)*. When the seed is planted, roots and a single seed leaf (the shoot) start to grow *(H)*. The genes in the seed's chromosomes determine the characteristics of the new plant.

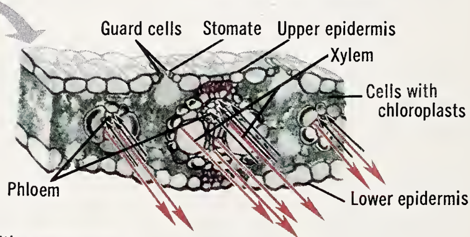


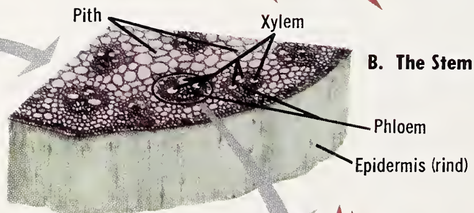
HOW A PLANT MAKES AND STORES FOOD Inside the leaf *(A)* are millions of cells in which there are tiny bodies (chloroplasts) containing chlorophyll, the green-colored matter that enables the plant to make sugar from carbon dioxide, water, and energy from sunlight. Carbon dioxide enters the leaf through tiny openings (stomates) in the thin epidermis. Water, with dissolved minerals, enters the plant through a thin wall of cells in its roots (follow the red arrows) and travels upward through tiny tubes (the xylem tissue). The amount of carbon dioxide in the leaf at any one time is regulated by the guard cells, which can open and close the stomates to let air in or water vapor out.

The sugar made in the leaves is changed by the plant into starch and stored in the pith *(B* and *C)*. The food is carried away from the leaves through more tiny tubes, the phloem tissue (follow the red arrows). The plant builds new tissues from the foods it makes.

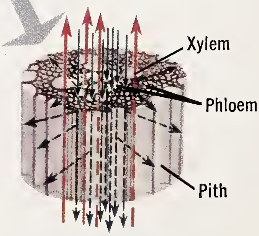
The xylem and phloem tissues, found in bundles *(C)*, are the plant's efficient conducting system, which takes the raw material absorbed by the smallest root hair to the tips of the tassels and the leaves. The thickened outer epidermis of the stem protects the inner tissues and gives the plant support.

A. The Leaf in Cross Section





B. The Stem



C. A Fibrovascular Bundle

offspring were tall. Not a dwarf plant appeared, even though he mated pure tall plants with dwarf plants again and again. He had made another important discovery.

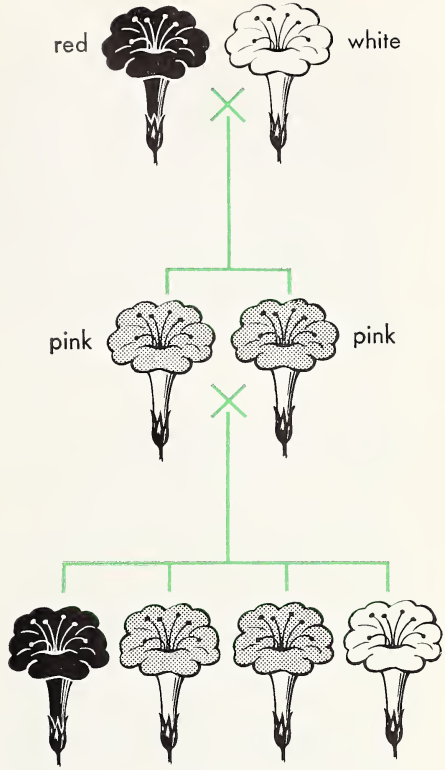
Mendel had found that the trait of tallness in pea plants masked, or hid, the dwarfness. This had to be true, since he had mated pure tall plants with ones that were pure dwarf. Not one dwarf plant had appeared among the offspring. In other words, even though the material from the nuclei of the dwarf plants was there, in the offspring the trait of tallness was *dominant*. The hidden trait of dwarfness Mendel called a *recessive* trait.

There are many dominant and recessive traits in your own inheritance. Brown or black eye color is dominant over blue eye color. Blue eye color is recessive. Dark hair color is dominant over blond.

Since the time of Gregor Mendel, other scientists have discovered that some traits are neither dominant nor recessive. The traits may blend, in fact. For instance, when a pure red-flowered four-o'clock is mated with a pure white one, the offspring are neither red nor white. They are pink (Fig. 214). Neither red nor white is dominant in four-o'clocks.

Hybrids

You may have heard of hybrid plants — hybrid corn, for example. What is meant by the term *hybrid?* It is the opposite of pure-line. When the pure-line tall pea plant was mated or "crossed" with a dwarf pea plant, the offspring was a hybrid. Even though it looked tall it still contained the hidden trait of dwarfness in its cells. It was no longer a pure-line plant. Pink four-o'clocks are also hybrids. They have in them something that makes for redness and whiteness.



214 Red × white four-o'clocks = all pinks. But pink × pink results in red, pink, and white four-o'clocks. The pinks are, therefore, hybrids; they have the characteristics for red and white in them.

The Discovery of Genes

Have you been wondering what it is in the nuclei of sperm and egg cells that decides the traits that will show up in the offspring? Since 1900, scientists have been looking for the answer to this question. After years of study they have found in tiny bodies the nuclei of cells. These microscopic bodies are called *genes*

(JEENZ). They set or determine the traits of the offspring. These genes are inside rod-shaped bodies called *chromosomes* (KROH-muh-sohmz) (Fig. 215). Thus, tall pea plants have genes for tallness, and pure dwarf pea plants have genes for dwarfness. The hybrid pea plant has genes for both dwarfness and tallness, but since the genes for tallness are dominant, the hybrid plant will be tall.

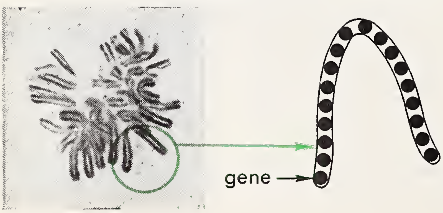
Useful Information for Plant and Animal Breeders

The facts about dominant and recessive traits, hybrids, and genes are most useful to breeders. They are tools which breeders use to grow the kinds of plants and animals they want. For instance, some kinds of the wheat plant, upon which the world depends for its bread, cannot live through a hard winter. Plant breeders found a kind that could stand the cold weather. They mated it with wheat plants that had other good traits. The hybrid wheat plant that was the offspring of this mating was winter-hardy. The breeders found that winter-hardiness was a dominant trait. They then knew that they could cross any kind of wheat with a winter-hardy kind and the resulting plant would be able to stand cold weather.

The breeder's job is a search for desirable genes. Desirable genes are those that will benefit man. Shorthorned cattle produce more beef than longhorned cattle; winter-hardy wheat produces good wheat that will not be killed by winter weather.

215 In the circle, a picture of a splitting chromosome under the microscope. At the right, a diagram showing an idea of how genes are thought to be arranged in a chromosome.

GENERAL BIOLOGICAL SUPPLY HOUSE



BROWN BROTHERS

216 Gregor Mendel, a monk, whose very important experiments on inheritance in garden peas form the basis of what we know of how plants and animals inherit their physical traits.

Are Inherited Genes the Only Cause of Traits?

If you have been thinking that traits are determined only by genes, you are wrong. Heredity is only part of the story. You have both inherited and acquired traits. Where and how you live and what you eat also have much to do with the traits you show.

A baby may have genes for good straight bones. However, without the right amount of vitamin D, the sunshine vitamin, his bones may not grow straight. The baby may get rickets from the lack of the D vitamin. Here it is the environment, not the genes, which is to be blamed for crooked bones.

A cow may have genes for good milk production. If the farmer fails to give the cow good food, fresh water, and the right care, the cow may never produce as much milk as she could. However, if she does not have the genes for good production of milk, a good environment cannot make her produce more than the genes have determined.

Plant and animal breeders work to produce better and better plants and animals. For breeding, they select those with the best inherited traits. By doing this, they make sure that the offspring will inherit desirable genes. Then the farmers and ranchers give these selected animals and plants the best environment possible. The best traits develop to their fullest in the best environment.

Yes, the facts about what heredity and environment can do for plants and animals also apply to human beings. They apply to you.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

asexual reproduction	fertilization	pollination
cross-pollination	grafting	sexual reproduction
cutting	ovary	sperm
egg	ovule	stamen
embryo	pistil	

1. a female cell
2. a part of a flower that holds pollen grains
3. the baby plant or animal in the early stages of its development
4. the carrying of pollen from one flower to another
5. reproduction from one parent
6. reproduction from two parents
7. the part of a flower that contains the ovary with its ovules
8. any portion of a plant (leaf, stem, root) used for growing a new plant by asexual reproduction
9. the male cell
10. the part of the plant that produces the egg cells
11. the transfer of pollen from the stamen to the pistil of the same or different flowers
12. joining the cut branch of one plant to another rooted plant
13. a part inside the ovary where the egg is to be found
14. the union of the male sperm cell with the female egg cell

Test Yourself

a. If you understand the key words below, you can place most of them correctly in the spaces in the statements which follow them. Complete the statements in your notebook. DO NOT MARK THIS BOOK.

acquired trait	genes	mutant
chromosomes	heredity	mutation
dominant	hybrid	pure line
environment	inherited trait	recessive

1. Gregor Mendel's experiments with . . . pea plants showed that the trait of tallness is . . . over the . . . trait of dwarfness.
2. The mule is the offspring of a donkey and a horse. It is a . . . animal.
3. The . . . in the parent cells determine what traits can be inherited by the offspring.
4. A trait that cannot be passed on from parent to child is an . . . .
5. A . . . is an accident of heredity.
6. We have learned that both . . . and . . . are important in the development of plants and animals.

b. Are the following sentences true or false? If they are false, rewrite them in your notebook to make them true. DO NOT MARK THIS BOOK.

1. Potatoes are usually grown by planting potato seeds.
2. The paramecium multiplies by dividing.
3. Asexual reproduction is a method used to make sure that a plant reproduces others like it.
4. All living things come from living things.
5. The offspring of two parent plants will always look alike.
6. Grafting is a form of sexual reproduction.
7. Pollen grains are sperm (male) cells.
8. A female cocker spaniel mated to a male cocker spaniel can produce only cocker spaniels.
9. The eggs of birds are fertilized after the eggs are laid.
10. In sexual reproduction two parent cells are needed.

GOING FURTHER

In the Laboratory and Field

1. Bring to your classroom an ear of corn showing some undeveloped kernels. Why did these kernels not develop?

2. Grow a carrot plant from a root (asexual reproduction). Be sure the carrot still has some green leaves at the top. Grow an onion plant from a bulb, and a begonia plant from a cutting.

3. *Egg development.* In the spring, collect frog or toad eggs. Allow some to develop at room temperature. Keep others in a cool place. Which develop faster? Keep a daily time record of their

growth. Make complete drawings of the stages of development.

4. You may be able to find some turtle eggs near the shore of a lake or stream, even though the female turtle usually covers the eggs with sand or soft soil. Take three or four of the eggs to your home or classroom, put them into a box of moist sand and set them in the sunlight. Be sure to keep the sand moist so that the eggs will not dry out too much. As soon as the little turtles hatch, put them into a terrarium where there are soil, water, and growing plants.

5. You may wish to raise guppies, a type of tropical fish. Get a book of instructions from a pet shop or library to help you. *Exotic Aquarium Fishes*, by William I. Innes, published by the Innes Publishing Co., Philadelphia, will give you the information you need.

6. Sow some radish or beet seeds in a row in your garden or in a box of soil in the classroom. When the plants are a few inches tall, decide which plants should be pulled out to make room for the best plants to grow. How do you decide which plants to pull and which ones to encourage? Does anything in this chapter help you with your decisions?

7. *Rat experiment.* If your school has white (albino) rats and hooded black rats, mate the two kinds. What will the offspring be? When the young rats are born, decide which trait is dominant.

Put on Your Thinking Cap

1. This article appeared in a newspaper:

COW COMPLETES TEST

With 776 pounds of butterfat and 19,545 pounds of milk to her credit, a registered Holstein-Friesian (HOHL-steen·FREE-zhun) cow has completed a 364-day production test in official Herd Improvement Registry. Her record averages approximately 25 quarts of milk daily for the period covered by her test.

217 At the left, the tiniest corn ear known — and the oldest. It was discovered in Bat Cave, New Mexico, and is said to be about 3,000 years old. At the right, modern ears of corn, the result of the plant breeders' skill. Corn has certainly changed.

LEFT: HARVARD UNIVERSITY NEWS OFFICE; RIGHT: STANDARD OIL CO. (N.J.)

Why would a dairy farmer go to the trouble of keeping records of the amount of milk produced by any one of his cows during a year?

2. Farmer A has a 100-acre farm. Farmer B has a 200-acre farm. Both are dairy farmers. How can Farmer A produce nearly as much milk as Farmer B? Assume that both can get enough feed.

3. In Florida and other Gulf states the dairy cows were never very good until they were mated with the zebu (ZEE-byoo) cattle from southern Asia. How did the breeders work to get the present successful dairy breed? You can read about this in the 1947 Yearbook of the U.S. Department of Agriculture.

4. A breeder of flowers wants to be sure that he gets only seeds that produce a yellow iris. In order to do this, he must get the pollen of a yellow iris on a pistil of another yellow iris. How can he do this?

5. Sometimes you see an ear of corn with kernels of different colors. What do you think is the reason for this?

Adding to Your Library

1. *The First Book of Conservation* by Frances C. Smith, Franklin Watts, New York, 1954. Important facts on how insects, birds, fish, animals, plants, and even people affect one another.

2. *Elementary Lessons in Gardening* by Paul R. Young, National Garden Institute, 1368 North High St., Columbus, Ohio, 1953. This booklet will give you many pointers on reproducing plants in the house and in the garden.

3. *You and Heredity* by Amram Scheinfeld, rev. edition, Lippincott, Philadelphia, 1950. This book is most interesting reading about the inheritance of man's traits. It discusses such traits as baldness, musical talent, red hair, and many others.

4. *Conserving Natural Resources*, Shirley W. Allen, McGraw, 1955.

5. *Lesser Worlds* by Nesta Pain, Coward, 1958. The fascinating story of life in the strange world of insects.

6. *Tropical Fish in Your Home* by Herbert R. Axelrod and William Vorderwinkler, Sterling, New York, 1958.

7. *The Birds* by Oskar and Katharina Heinroth, University of Michigan Press, 1958. This book really brings our feathered friends to life. If you like birds, you'll like this book.

8. *Cold Noses and Warm Hearts*, Preface by Corey Ford, Prentice-Hall, 1958. All about dogs.

9. *Animal Close-ups*, Theodore McClintock, Abelard, New York, 1958.

10. *The Animals of Doctor Schweitzer* by Jean Fritz, Coward, 1958.

11. *Snakes in Fact and Fiction* by James A. Oliver, Macmillan, 1958.

12. *Seals, Sea Lions and Walruses* by Victor B. Scheffer, Stanford University Press, 1958.

Careers for You

Farmers who have sufficient knowledge of breeding plants and animals are needed to specialize in one or more kinds of farming: breeding dairy or beef cattle, raising poultry for eggs or meat, growing better vegetables, fruit, or grains.

Geneticists (juh-NET-uh-sistz) (scientists who know how to carry on research connected with breeding) are needed in colleges and government experiment stations.

Scientists are needed for studies (*research*) to help the farmer. For this work they must be well trained in many kinds of biology and chemistry.

A *Farm Bureau agent* and a *Home Bureau agent* are employed in each county to advise and help farmers and their families. A Farm Bureau agent is usually a graduate of a college of agriculture; Home Bureau agents, usually women, are expert in the sciences that deal with foods, clothing, and other work of the home.

CHAPTER 21

Wise Use of Our Inheritance

Trees take a long time to grow. The tree above, and others like it, the plants and animals in our forests, depend on the soil. All this is your inheritance. It is not to be wasted, but used for better living.

Do you work to earn some of the money you need? Most high school boys and girls do. But suppose you spent foolishly all that you earned or used all your allowance on foolish things. Would you be better or worse off a year from now? You would have nothing to show for your hard work.

In just the same way, our soil, water, forests, and our living things can be used up unwisely. Once they are spent, it is hard work to "earn" them back again.

Our state and national governments are doing much to make us see the need. *Conservation* is not merely saving; it means, rather, using wisely and protecting valuable plants and animals. In that way we can have enough for our use and enough for our children and their children's children. As an example of conservation, the wise use of our resources, let us look at what our government has done to save the Columbia River salmon, an important source of food for many people.

At the same time every year, salmon come in from the ocean and start up the Columbia River. Nothing stops them. They jump small falls. If they fail at the first try, they jump again and again until they gain the quiet waters above. Where the falls are too high for the salmon to jump, men of the conservation service have built "fish ladders." These ladders are a series of stone basins (Fig. 218).

Finally, in the upper branches of the river, the females lay their eggs and the males deposit sperm over them. Then the adult salmon die. Soon the young of the salmon are hatched (Fig. 218).

What happens to the young? They grow for a while and then start on a long, hard journey down the river to the ocean. Those that do not die on the way grow to adults in the ocean. In about three years they start the long trip back up the same river, over the fish ladders to the exact place where they were hatched. Here they spawn and die as their parents did.

When the huge Grand Coulee Dam was built on the Columbia River, scientists of the Conservation Service knew that the fish could never pass this great dam on their journey up the river. So they began a conservation experiment.

First, the experimenting scientists caught thousands of the female salmon and shipped them to hatcheries. There the eggs of the females were removed. The milt of the male, which contains the sperms, was mixed with these eggs. As soon as the young hatched, they were placed *below* the Grand Coulee in the rivers which flow into the Columbia River. Many of these fish were clipped through the tail so they could be recognized, and then allowed to swim out to the sea.

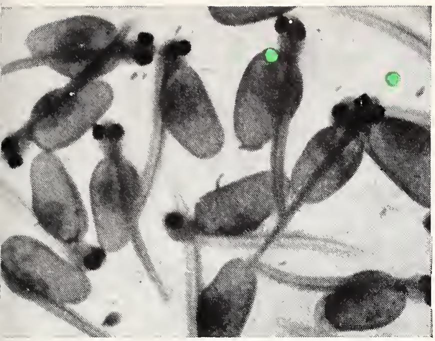
The scientists knew that the salmon would come back to spawn, but would they try to get up the face of this dam and kill themselves trying? Or would they go back to the rivers below the dam in which they had been placed?

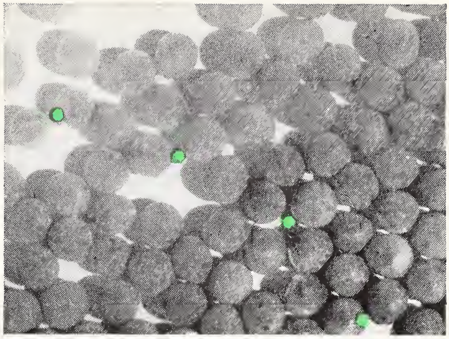
When spawning time came (three years later), the grown salmon returned. The men watched anxiously to see if their experiment would work. Sure enough, here were the fish with marked tails. They were not killing themselves on the rocks of Grand Coulee; instead, they were stopping at the streams below in the exact spot where they were first placed by the scientists. A valuable food supply and a quarter of a billion dollar industry had been saved by the skilled scientists of the Conservation Service.

The Problem

Not more than 150 years ago, states like Pennsylvania, Ohio, and Indiana were covered with forests in which roamed many wild animals. The forests have largely disappeared, cut down to make room for homes, factories, and farms. The animals, robbed of their natural homes and killed for food or for sport, have been disappearing rapidly. Once there were great herds of bison (buffalo) roaming the plains. Now the few remaining bison are in wildlife refuges, like the one in Jackson Hole in Wyoming. There they are fed, protected, and cared for on government land.

Birds, fish, and useful wild mammals are protected by game laws. Hunting and fishing seasons are kept short so that not too many of the animals will be killed. Limits are set



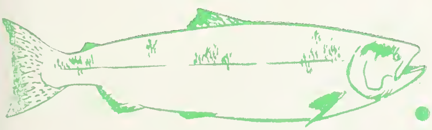


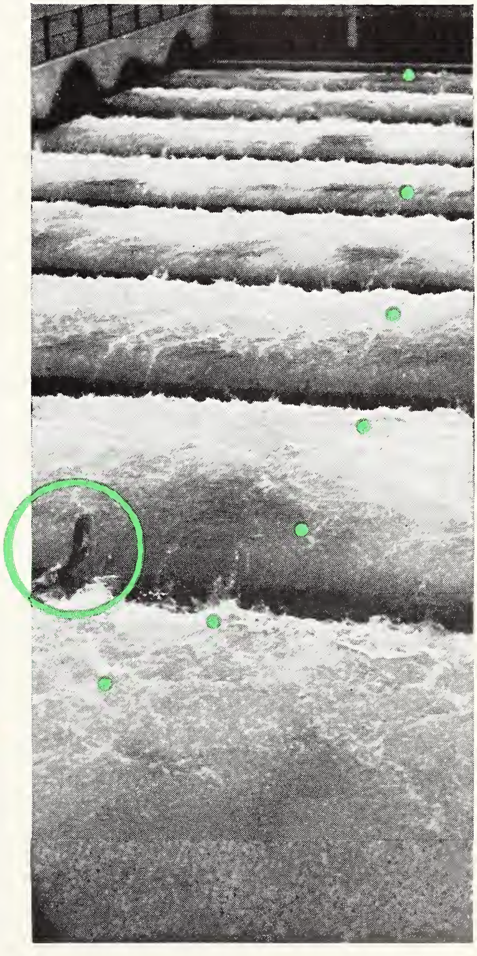
S. FISH AND WILDLIFE SERVICE AND STANDARD OIL CO. (N.J.)

also on the number of each kind of animal that a sportsman may take. During the rest of the year, the game is allowed to reproduce. Thus the killed animals are replaced.

No Limits to the Catch

Just as the catch or bag is limited for certain animals, so there is no limit on others. Some animals are harmful to our food supply, and their numbers must be kept down. For instance, in many states there is no limit in the hunting season on the number of rabbits that may be taken. Rabbits reproduce very fast. They may ruin vegetable gardens or crops or destroy trees and shrubs by gnawing at the bark. Hunting keeps the number down.





218 Here are salmon jumping the fish ladders at Bonneville Dam on the Columbia River. The ladders help the salmon reach the upper river where they spawn and lay the eggs you see, *above right*. These develop into the young salmon, or fry, *above left* (shown with yolk sacs they use for food).

Why must we limit the catch, or have a closed season, for some animals? Why do we have open season on others — killing all the animals we can? The answer lies in the meaning of two words, *adaptation* and *balance*.

BEING ADAPTED

Adaptation means being suited to live and reproduce in certain surroundings or *environment*. For instance, the body and fins of a fish enable it to swim in water. Its gills enable it to get oxygen from water. A fish is not adapted to living on land; it dies in such an environment. A rabbit is adapted for breathing air. So are you. Your lungs are not adapted to breathing oxygen from water.

Birds are adapted to flying. Their hollow bones give them light bodies; their wings and tails, as well as their streamlined bodies, fit them for movement in air (Fig. 219). Their oiled feathers protect their bodies against rain or the water in which some birds swim.

Desert plants, like the cactus, can live on small amounts of water. Many of them store it for use in times of drought (Fig. 219). However, you will find no beech trees or geraniums in a desert. They are not adapted to a desert environment.

The Price of Not Adapting

No doubt you have visited a museum and seen the bones of ancient reptiles, such as *dinosaurs* (dy-nuh-sawrs) (Fig. 219). You may have seen the huge king dinosaur, 18 feet high, its great head filled with pointed teeth, each the size of your fist. You may have seen the thunder reptile, some 40 tons in weight. These creatures do not exist today.

Why did they die out? One theory is that the land in which they lived changed from a wet, lush, swampy one to a land that was fairly dry and prairie-like. Many of these huge, fierce-looking reptiles lived on plants. When the plants they used as food began to die out, they died out too. The dinosaurs were not fitted to the new environment.

How would you judge whether a plant or animal is well adapted to its environment? By the fact that it lives? Scientists use at least two standards to test adaptation. They ask: Does the living thing reproduce its own numbers? How widely is it distributed, that is, where is it to be found on the earth? Let us apply these standards to several test cases.

The Emperor Penguin

The scientists with Admiral Byrd's expedition to the Antarctic carefully studied the habits of the emperor penguin. They noticed that it could not fly. They observed how its young hatched in the below-zero weather. They noticed how tough the bird was. They saw how easily it got its food — fish, shrimp, shellfish. It had no enemies to speak of, and its numbers remained constant. It is well adapted to the cold of the Antarctic. It is found in a fairly small region because it needs a special environment in which to live.

Man

Because he has a remarkable brain, man is especially good at mastering many kinds of environment. His air-

planes enable him to compete with the birds; his submarines and ships with the fish; his automobiles with the horse. His clothing and his heating devices enable him to master cold climates; his refrigeration systems enable him to master hot and cold climates. He is increasing his numbers. He has spread over the earth. He is, therefore, well adapted to the present environment. His environment takes in nearly the whole earth. This entire book is really the story of man's ability to master his environment.

If we apply the standards of adaptation, we see that both the emperor penguin and man reproduce their numbers. The emperor penguin is adapted to a special environment, but man can master almost any environment.

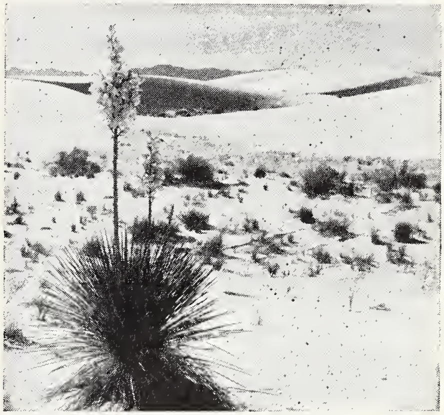
Man's Chief Competitors

Scientists who study insects and their habits tell us that if we should stop our fight against insects for one season, we should soon lose our dominant position on earth. The scientists point out that there are almost 600,000 different kinds of insects. They live in all parts of the world. They greatly outnumber man. Man's fight against insects goes on without end. Right now we are holding our own. However, disease-carrying insects make it impossible for man to live in certain areas of Africa.

Another of man's competitors is a group of animals called *rodents* (ROH-d'nts). In this group are rats, mice, rabbits, prairie dogs, beavers, and other gnawing animals (Fig. 220). They reproduce in large numbers and eat grains and other plants that man uses.

IN THEIR ENVIRONMENT

THESE BECAME ADAPTED



BUT THIS DID NOT

NATIONAL PARK SERVICE AND AMERICAN MUSEUM OF NATURAL HISTORY

219 By slow change in heredity birds and desert plants became adapted. The dinosaur may have changed too slowly.

The insects and the rodents are so well adapted to the environment that they compete with man wherever he is. Man has to keep them in check, or they will destroy his food supply or kill him with the diseases they carry.

So man tries to keep his competitors' numbers down. He tries to keep a balance between himself and his competitors. In fact, he tries to keep a balance among all plants and animals.

BALANCE

There are about one million different kinds of animals and one-third as many different kinds of plants. How do these plants and animals live together? Why don't the biggest, the most powerful, or the fastest-multiplying plants or animals kill off the others and thus cover the earth with their own kind? Do you think they could do it? Here are several cases which will help you decide.

220 This chipmunk may do little harm. But he is a rodent. So are rabbits, rats, and mice, which may do a great deal of damage to crops.

NEW YORK ZOOLOGICAL SOCIETY

Mistake No. 1

In a Southern fishing town, the fishermen got together at town meeting and voted a bounty for every heron brought in (Fig. 221). The herons, they said, were destroying their fishing grounds.

The bounty plan worked. Herons were brought in by the dozens. Soon there were very few herons about. For a good number of years the fishermen enjoyed heavy catches. Then their catches began to get smaller again. At this point scientists were called in for advice, and here is what they found.

After the herons were killed, the fish began to multiply. They fed on water plants. However, the water plants could not keep on reproducing fast enough to feed the fish. The plants, surprisingly enough, depended on the herons. The herons' droppings supplied some of the chemicals the plants needed to make food. The plants in their turn furnished the fish with food for growth and reproduction. The fish furnished men with a livelihood and the herons with food. Thus, you see, there was a delicate balance between heron, fish, and water plants. The fishermen's mistake was to destroy this balance.

Mistake No. 2

In pictures you have seen of the African or Brazilian jungles, everything seems just to grow. That is not so, as the early Dutch settlers in Africa found out.

They sent out expeditions to kill the lions and leopards, which sometimes took one or two of their farm animals. Lions and leopards are called *carnivorous* (kahr-NIV-er-us) ani-

mals, or *carnivores* (KAHR-nih-vohrs); that is, they eat meat. Where the hunters killed most of these carnivores, the grazing animals, or *herbivores* (HER-bih-vohrs), deer and antelope, giraffe, wild boars, and rodents increased in number. Why? They had been kept down by the carnivores. Without the carnivores to keep them in check, they ate up the natural vegetation and then began to eat the farmers' crops.

In one area the herbivores made farming impossible, and the Dutch had to leave. They had learned that it was unwise to upset the balance between the carnivores and their prey, the herbivores, even though it meant that some of their cattle would be eaten.

The jungle is one large community, each living thing fitting into its proper place. Carnivores eat herbivores, herbivores eat plants, and green plants make their own food from the soil, water, and air.

The idea is summarized in an old rhyme:

> Great fleas have little fleas
> Upon their backs to bite 'em.
> And little fleas have lesser fleas,
> And so *ad infinitum.*[1]

Other Mistakes

Suppose man were to introduce an animal into an environment where it had never lived before and allow it to compete with the animals and plants already living in balance. What would happen then?

Leopold Trouvelot (troo-veh-LOW), a New Englander, brought the gypsy moth here from France in 1869. He wanted to breed a better silkworm moth. Unfortunately, some of the moths escaped. By 1900, they had become a great pest in New England, eating their way through orchards and stripping shade trees of all their leaves. Today, although they are being fought, they have not yet been brought under control.

[1] (AD · in-fih-NY-tuhm). It means "endlessly."

AMERICAN MUSEUM OF NATURAL HISTORY

221 The heron feeds on fish. He is part of a cycle; his droppings and those of birds like him help plants grow. The fish feed on the plants. Result: a greater number of fish than the heron eats.

You can see that, although there are countless plants and animals, they are governed by two principles: First, they are adapted to the environment in which they live. Second, they live in a balance in that environment. These principles apply to elephants, Baltimore orioles, men, wheat, fish, game animals, bamboo, mosses, germs — to all living things.

Balance and Conservation

The Conservation Service protects only those animals and plants that need protection. For instance, in some

states, such as Michigan and Ohio, it is against the law to hunt quail. These valuable birds, which eat weed seeds and insects, need protection, because they can just about keep their numbers at the same level.

Wild flowers are protected, too. When certain flowers like wild orchids (lady's slippers), arbutus (ahr-BYOO-tus), dogwood, and mountain laurel are picked too freely, they become scarce. Laws have been passed to make it illegal to pick them. Many persons are learning to enjoy these flowers by looking at them or photographing them.

These few examples point to a very important principle of conservation: Protect the helpful wildlife whose numbers are decreasing, and reduce the numbers of those that damage crops or other animals.

Another principle is equally important: Be careful not to disturb the balance of nature by killing all of one kind of living thing or introducing a new one without its natural enemy.

Balance in a Forest Sanctuary

Wildlife refuges are set aside as homes for plants and animals that are in danger of becoming *extinct*, that is, of being wiped out completely. There is probably one or more of these sanctuaries near where you live. If you visit it you will learn much about wildlife.

Come with us to a wildlife sanctuary. Sit down here in the shade of a big tree and watch. There is a rustle in the underbrush. A big black snake moves along over a rock. The black snake is a good catcher of rats and mice. A good number of snakes helps keep down the number of mice.

There is a hawk gliding in the air overhead. Suddenly he swoops and dives down into the brush. When he rises, he has a small bird in his claws. You wonder why hawks should not be killed. They must be a danger to the other birds, you think.

In a sanctuary, only man is kept from killing plants or animals. All other living things live in balance, because they are not disturbed by man. Of course, some animals kill others, but they kill for food. Because each animal lives on other plants and animals, all of them are kept in check. Living things that depend on each other for food make a *food chain*. Look at the food chain shown in Fig. 222. The hawk cannot increase its numbers faster than its food supply. Neither can the snake, nor the mouse. In any food chain, if the food supply goes up or down, the number of plants or animals also goes up or down.

If all hawks, snakes, and foxes in the sanctuary were killed off, rats, mice, and rabbits would multiply in great numbers. Their natural enemies would be gone. They would feed on the bark of trees, and in a few years the trees would be gone. With the trees gone, birds and woods mammals would leave. The water and soil would not be held back; the rivers would be choked with mud, and the fish would die. You can see that living things live in a delicate balance that should not be upset.

Balance on a Farm

Farmers, too, are learning that keeping the balance is important. Farmer A cuts down the thickets of shrubs and trees around his cornfield. He thus drives off the quail that nest

222 Who feeds on whom? Do you see how some animals keep others under control?

in these thickets. They go to a neighboring farm where the thickets have been left. Next year the chinch bugs come, and the corn on Farmer A's farm is ruined by the bugs. On the neighbor's farm, the quail eat so many chinch bugs that the corn is saved. The quail help to balance the harmful insects.

DESTROYING PESTS

Some of the worst enemies to our production of plants and animals are insects.

You know that many insects are helpful. Without bees, for instance, we should lose $75,000,000 yearly in a honey crop. Fruit trees and other plants would not be cross-pollinated. The silkworm (one of the early stages of the silk moth) produces about 120 million pounds of silk per year. The lac insect produces a material used in making shellac. Still other insects, like the ladybird beetle and the praying mantis, help us to kill other insects that are harmful.

Many insects are pests. They destroy at least 10% of our crops each year. The Colorado potato beetle can cause serious damage to the potato crop. Corn worms can ruin a farmer's corn crop. The Mediterranean fruit fly almost destroyed the Florida fruit industry before it could be wiped out. Table 13 lists some of our insect enemies and tells how they can be controlled.

Insect Life Histories

The small white and yellow cabbage butterflies do much damage to the cabbage crop. The butterfly lays

TABLE 13 Some Insect Enemies

The Pest	*Its Destructive Work*	*How to Control It*
Codling-moth larva	Feeds on apples	Poison spray
Corn earworm	Feeds on corn	Crop rotation, poison spray
Cotton boll weevil	Larva feeds on cotton pods, called bolls	Spraying
Western grasshopper	Feeds on all grasses	Chemical spraying, fire (when large numbers infest the fields)
Gypsy moth	Feeds on all trees (New England)	Poison spray, sticky bands on trees
Potato beetle	Feeds on potato vines	Sprays
Chinch bug	Feeds on corn	Sprays
Japanese beetle	Feeds on wide variety of plants	Sprays
Cottony-cushion scale	Sucks juice of citrus fruits	Ladybird beetle
Flies, mosquitoes	Annoy livestock; carry disease	DDT*

* Spray carefully. With all sprays, follow instructions, and do not breathe in spray, which is thought to be harmful to man and livestock.

its eggs on a cabbage leaf. In a week or so, each egg hatches into a tiny, green, wormlike animal, a *larva* (LAHR-vuh). These larvae feed on the cabbage leaves. When they are about an inch long, they form a *pupa* (PYOO-puh) (Fig. 224). While they are in the pupal stage, they change from a wormlike creature to an adult butterfly. The butterfly then lays more eggs.

This life cycle, made up of four stages — egg, larva, pupa, and adult — is the life story of butterflies, moths, beetles, flies, bees, and ants. Can you spot the clue to one method of destroying the cabbage butterfly? Does the butterfly eat cabbage? Does the pupa?

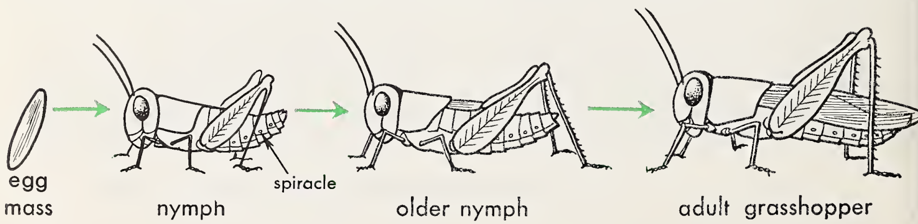
It is the larva or caterpillar that chews holes in the cabbage leaves. Therefore, if we wish to destroy the enemy of the cabbage plant, we must kill the larvae — as young as possible — so that they can do the least damage.

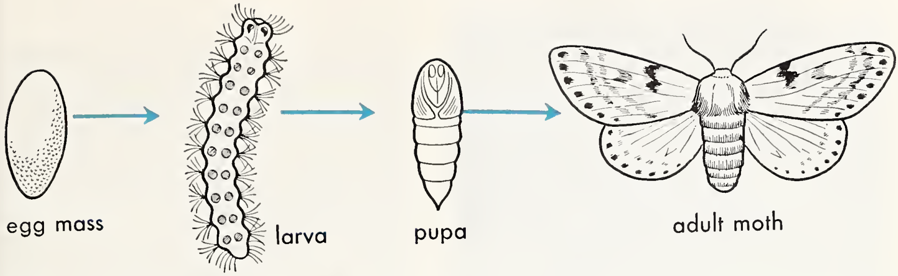
It is important to be able to recognize the different stages of insect life (Fig. 224). You may be able to destroy harmful pests in the egg, larva, pupa, or adult stage before the plants have been damaged.

When you see a caterpillar you will know that it is the larva of a moth or butterfly. However, most larvae of beetles are tan or white grubs.

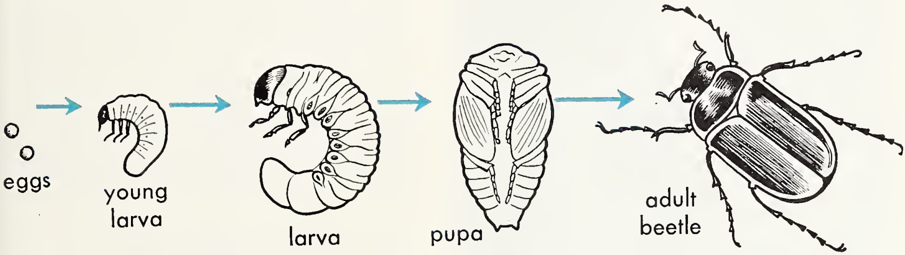
The pupal stage of some of these insects may be different. Moth cater-

223 The development of a grasshopper. Can a nymph fly? How does the development of the grasshopper differ from that of a moth? from that of a beetle? *Project:* In the summer collect the nymphs of grasshoppers. Then feed the nymphs on grass till they become adults.





224 *Above*, the development of a moth. *Below*, the development of a beetle. The moth lays a mass of tiny eggs. Each egg then develops as shown. What are the stages in the development of a moth? of a beetle?



pillars spin a cocoon about themselves. Some spin it in the ground, and others attach it to a leaf or stem.[1]

The larva of a butterfly or beetle is so different from the adult that it is hard to believe that one comes from the other. However, with insects like the grasshopper, cricket, katydid, and roach, it is easy to recognize the young. They look like the adults except that they do not have wings. They are called *nymphs*. The wings develop gradually (Fig. 223).

Grasshopper nymphs hatch from eggs laid in the ground in the fall.

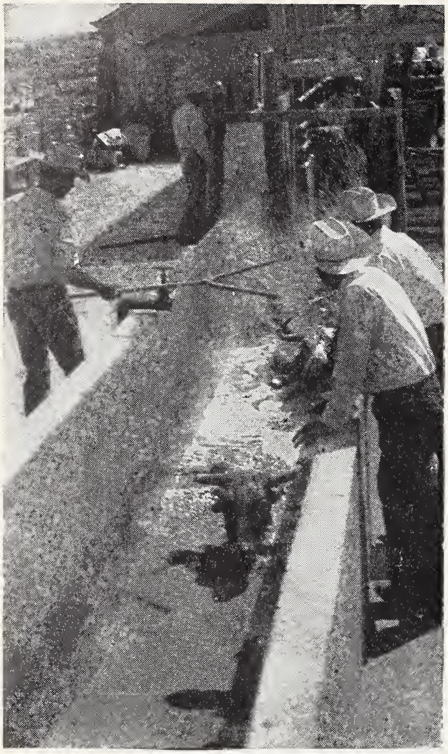
Chewing and Sucking Insects

A poison put on the food of a chewing insect will get into its stomach and kill it. But we must be careful that a vegetable is not sprayed with a poison that is harmful to humans. *Rotenone* (ROH-teh-nohn) and *pyrethrum* (py-REE-thrum) are harmless to man. These two insect poisons are often used by gardeners on such vegetables as cabbage, broccoli, and Brussels sprouts. No matter what chewing insect attacks your plants, remember that a *stomach poison* will kill it. Always wash fruits and vegetables to remove any chemicals used in sprays.

For sucking insects, such as aphids (plant lice), a different kind of poison is needed. Sucking insects do not chew the leaves; they pierce the leaf or stem and suck the sap. How, then, can sucking insects be killed?

All insects breathe by means of openings in the body called *spiracles* (SPY-ruh-c'ls) (Fig. 223). These openings connect with a great number of

[1] Butterfly caterpillars make a shiny case called a *chrysalis* (KRIH-s'l-is).



U.S. DEPT. OF AGRICULTURE

225 Getting rid of pests is one job of the farmer and rancher. Here cattle are being sprayed and dipped against cattle ticks.

air tubes which run to every part of the body. Sucking insects can be killed by a poison that closes up their spiracles and thus shuts off their supply of air. This type of poison is called a *contact poison*. A spray or dust containing tobacco juice or nicotine sulfate (sometimes sold as Black Leaf 40) is such a contact poison. A mixture of kerosene and soapsuds can also be used. Most household insect sprays get into the insect's body through the spiracles.

The poison called DDT enters an insect's body and poisons its nervous system. DDT will kill insects that walk through it. Care should be taken not to breathe sprays or dusts or get them on the skin. Certain kinds of sprays or dusts make some people ill. Of course, any dusts or chemicals used against insects should be kept out of reach of children.

A poison like rotenone or DDT can be used to kill both chewing and sucking insects. When DDT was first used, it was thought to be the answer to the problem of harmful insects, for example, to the problem of killing flies around cow barns. But scientists soon found that DDT seemed to be harmful to mammals, and perhaps to human beings. They found, too, that it could kill bees. In some states, dairymen are no longer using DDT around cows that are producing milk.

The Farmer Against Insect and Other Pests

The farmer has many ways to protect his animals from insects and other destructive pests. He sprays his barns and chicken houses. He dusts his poultry with insect-killing powders to get rid of bird lice. He sprays or dips his cattle and sheep in creosote to get rid of ticks, mites, and lice (Fig. 225). He protects his young chicks from rats and weasels by building the kind of houses for them that these animals cannot enter.

The farmer and the gardener have some very valuable helpers in their fight against insects, rats, mice, and weeds. These helpers are the birds.

Birds Are the Farmer's Allies

What is inside a bird's stomach will show you how birds serve the farmer. They eat the insects which feed on the farmer's crops. They

devour quantities of weed seeds. Some birds eat small rats and mice.

Here is what some scientists discovered by examining the contents of birds' stomachs. One yellow-billed cuckoo had the remains of about 275 caterpillars in its stomach; a starling had eaten some 300 different kinds of insects. (Even the much-hated starling was found to be helpful.) A killdeer had the remains of 300 mosquito larvae in its stomach, while one nighthawk had destroyed 340 grasshoppers, 52 bugs, 3 beetles, 2 wasps, and 1 spider.

Other birds had a different diet. A ring-necked pheasant had eaten about 8,000 chickweed seeds; a mourning dove had gathered 700 weed seeds.

Hawks and owls eat large numbers of mice, rats, and moles. Robins, in spite of the fact that they eat a few cherries, live chiefly on worms, grasshoppers, beetles, and bugs, with some wild fruits and berries.

As you may remember from your reading in Unit 4, many of our birds migrate to the southern United States and to countries south of the United States in the winter. To protect these birds during their stay in other countries, migratory bird treaties have been made between our country and the countries to which the birds migrate.

Man Against a Beetle

A grim fight is now being waged against the Japanese beetle. In 1916 some of these beetles were brought by accident from Japan in a clump of iris plants. They came first to the area around New York, but they are rapidly spreading to the West. They do much damage to lawns during the larval or grub stage, and even more damage as adults to flowers, fruit, and foliage of trees. The eggs are laid in July. The grubs stay in the ground until late June. In spring they feed on grass roots; in May and June they go through the pupal stage; in late July they come out of the ground as adult beetles and begin to feed on all sorts of plants.

Scientists have been battling these beetles for several years. Dr. G. F. White, an entomologist (en-tuh-MOL-uh-jist) — a student of insects — began a study of the reason why areas that had been heavily infested with Japanese beetles seemed to have fewer of them after a time. After two years of study, he said that he believed that a disease, called "milky disease," had been destroying the grubs. The milky disease is caused by bacteria that attack the grubs, making them turn a milky color and die. Wherever you suspect that Japanese beetles are underground, you can spread the bacteria of this milky disease. Chlordan dust is also used to kill the larvae of Japanese beetles.

The natural enemies of the Japanese beetle have been imported from Japan. One of these is a wasp

226 Japanese beetles feeding on an apple. *Project:* Discuss ways of controlling plant pests in your state and make a plan for getting rid of them.

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227 Wheat rust. The flaked stems of the wheat are part of the damage the rust fungus causes to this important grain. *Project:* If you live in a farm area, or have a garden, collect samples of damage done to crop and garden plants by fungi. Exhibit them in class.

whose young feed on the grubs of the beetle. Many thousands of wasps have been bred by the Department of Agriculture and released into the fields to kill the beetle.

Man Against the Mediterranean Fruit Fly

In the spring of 1929, Florida was invaded by one of the worst of all citrus fruit pests, the Mediterranean fruit fly. Congress voted more than $7,000,000 to fight it before it could spread to other states. About 1,000 separate orchards needed treatment. If these pests had been allowed to live, all the oranges, tangerines, and grapefruit of the Gulf states would have been damaged. These are the steps that were taken:

1. All fruit trees were sprayed with poison.
2. All fruits on the infested trees were destroyed.
3. All states to which fruit had already been shipped were warned.
4. No fruit could leave Florida; the state was under quarantine.

This was severe treatment, but it worked. The Mediterranean fruit fly was under control in about one year.

FUNGUS PESTS

Not all pests are animals; some are plants. Have you ever seen an ear of corn or a stalk of wheat stained by a black powdery material (Fig. 227)? If you examine some of this powder under the microscope, you will find that it is made up of thousands of *spores*. Spores, you remember, are the tiny reproductive cells of fungus plants.

Man Against Fungus Pests

Fungi are simple plants that have no chlorophyll. Since they have no chlorophyll, they cannot make their own food. They must, therefore, get their food from other plants, animals, or nonliving matter.

The black spores on oats or corn are produced by *smut* fungi. They cause great damage to our grains. Some smuts can be controlled by treating the seeds before planting. Corn smut cannot be controlled in this way because the smut fungus infects the growing plants. The best way to control these fungi is to breed corn, wheat, oats, barley, rye, and other plants that are resistant to smut disease.

Rust fungi that are very much like the smuts cause even more damage. By learning about the life cycle of rust fungi, scientists have found a way to control them. It has been found that wheat rust fungi spend one part

of their life on the native barberry bush. We say that wheat rust has two *hosts*. A host is a plant or an animal on which the fungus grows. For the first part of its life, the host of the black stem rust is wheat. For the second part the host is the native barberry. Therefore, if the barberry can be destroyed, the wheat rust cannot complete its life cycle. Since 1918 the government has been killing off native barberry bushes, especially in the valley of the Mississippi, where so much of our wheat is grown. They are getting the wheat rust under control by this method.

Molds and Mildews

No doubt you have seen molds. They, too, are fungus plants. If you have not done so before, grow some bread mold so that you may look at it under the microscope. Expose a piece of bread to the air for about ten minutes. Then place it in a jar in a warm place. Add a few drops of water. Close the jar. In a few days you will see a fuzzy growth; in a few more days the bread mold will be producing spores in small black bodies like the head of a pin.

How can you prevent mold from forming on foods? If you keep foods covered so that mold spores from the air cannot fall on them, and store them where they are dry and cool, molds will be less likely to develop.

Mildew spores, too, are found almost everywhere. They are fungi that will grow on plants, leather, and clothing — on any material where there is enough moisture, warmth, and food. Mildew often grows in the hot, humid days of summer. Good ventilation will usually prevent its forming, however.

Preventing Growth of Fungi

You can see that molds and mildews need (1) food, (2) warm temperatures, (3) moisture, and (4) oxygen. We can take the water out of foods (dehydrate them). This denies moisture to the fungi. We can freeze foods or refrigerate them, and deny the fungi the warmth they need for growth. Or, we may can foods and keep the air away. Scientists have also developed ultraviolet lamps that help kill mold spores.

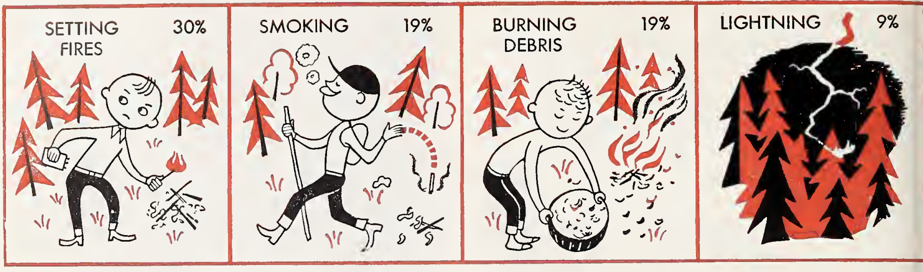
The spores of fungi are everywhere. Much food is wasted because mold is allowed to form on it.

PROTECTING OUR FORESTS

The United States Forest Service reports that there are, on the average, about 510 forest fires a day. They damage about 2% of the trees in our forest areas annually. In 1894 the great Hinckley fire in Minnesota destroyed timber worth $25,000,000, killed 418 people, and burned 12 towns. In Pennsylvania, nearly 2 million acres of forest land have been destroyed by fires. In 1947, Maine forest fires destroyed several towns and resulted in $30,000,000 damage. Fortunately, valuable species of pine, spruce, hemlock, birch, maple, oak, beech, and aspen have reseeded themselves over 67% of the area.

Who is responsible for these fires? Usually man. More than one-third of our forest fires are set by careless or ignorant persons. Smokers and people who leave trash fires unattended start many of them. Lightning starts fewer than one in ten. A lighted match thrown carelessly aside

MAJOR CAUSES OF FOREST FIRES



may be responsible for a fire like the Tillamook forest fire in Oregon. In 1933, this fire burned some 267,000 acres, at a loss of $350,000,000 to labor, industry, and the public.

However, insects and disease destroy more than twice as much timber each year as does fire. The Engelmann spruce beetle in the Rocky Mountains destroyed 1,600 square miles of spruce trees between 1939 and 1948. The elm leaf beetle is carrying a disease from elm tree to elm tree in the eastern states. Hundreds of elm trees are already dead; others are dying fast. Some are being saved, for a time at least, by being sprayed with a poison solution. Shade tree experts suggest planting trees that are resistant to disease.

Guarding Our Forests

Our forests are being watched over by the trained men of the United States Forest Service. Many states employ foresters and rangers. In Michigan, for instance, foresters and rangers watch over 7 million acres of private, state and national forests. From high towers they watch for fires day and night. Patrolling is also done by air. Trained fire crews are on call to answer any alarm.

In addition, about 900,000 acres of young trees have been planted in Michigan. These trees are planted sometimes for windbreaks, sometimes for farm wood lots, and sometimes to reforest sloping land.

Mainly, however, trees are now being planted as crops with a long life. Seedling trees replace trees that have been cut down in both private and government forests. Government and industry are co-operating to save our forests.

Conservation Makes America Richer

The program of conservation of our helpful plants and animals is an important part of our work of im-

HOW TO PREVENT FOREST FIRES

proving biologic production. Again, science helps us to better living.

We need to do three things if we are to conserve our natural resources. We must first guard them against destruction by man, pests, and fire; second, we must keep the balance; third, we must give the plants and animals we want to conserve the best environment for their growth.

Conservation practices are based on scientific work, as you have learned here. You can help personally by taking and keeping this pledge:

> ***Conservation Pledge***
>
> I give my pledge as an American to save and faithfully to defend from waste the natural resources of my country — its soil and minerals, its forests, waters, and wildlife.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after the word. Watch out! Not all words are defined. DO NOT MARK THIS BOOK.

balance of nature	host	smut
conservation	larva	spiracles
contact poison	mold	spores
food chain	pupa	stomach poison
fungus (pl., fungi)	rust	wildlife sanctuary

1. protection and wise use of natural resources
2. having enough of different kinds of living things so that all will have food, but none will multiply too rapidly
3. a place where all living things are protected against mankind
4. a line of plants and animals that feed upon or are eaten by another in the line
5. the caterpillar or grub stage of insects
6. the resting, changing stage of insects
7. a poison that kills insects by shutting off their supply of air
8. a plant on which a fungus grows
9. the reproductive parts of fungi

GOING FURTHER

In the Laboratory and Field

1. Write to your state conservation commission to find out if there are any school forests in your state. Perhaps your school would like to take part in one that has been started, or start one in your part of the state.
2. Survey the trees in your schoolyard, on your street, or in the nearest park to see what needs to be done to save them. Are there broken branches or openings in the bark that should be painted with creosote to keep out wood-boring insects and fungi of disease?
3. Make birdhouses and bird feeders for use at the proper time of year.
4. Begin an insect collection. Collect live insects on their food plant; collect others for mounting. See "Adding to Your Library" for a reference on collecting insects.
5. If you live on a farm, get a sample of corn smut or wheat rust. Examine the spores under the microscope. Find out what grains are resistant to these diseases. Your County Farm Bureau agent can help you.
6. Learn the Conservation Pledge. Letter it at the top of a chart and persuade as many of your schoolmates as possible to sign it.

Put on Your Thinking Cap

1. In a southern state a bird called the myna bird eats cherries and other small fruits, but also eats tent caterpillars and other harmful insects. At a local meeting, the planters are discussing a drive against the myna. What would you say?
2. If there is a bill in Congress to spend money on scientific research to improve plant production, should it be passed? Why?

Adding to Your Library

1. *Conservation* by David Cushman Coyle, Rutgers University Press, 1957.
2. *The Friendly Forests* by Alma Chesnut Moore, Viking, 1954. "An age builds up cities, An hour destroys them: In a moment ashes are made, But a forest is a long time growing." (Seneca)
3. Your school may also wish to buy *American Bird Song Records*, a collection of recordings on disks, by Albert R. Brand Bird Song Foundation, Cornell University Press, published by Comstock Publishing Co., Ithaca, N.Y.
4. Write to the American Forest Products Industries, Washington, D.C., for their booklets and charts showing the things that industry is doing to preserve our forests.
5. Guidebooks that will help you identify the different kinds of plants and animals are to be found at the end of the hobby section, "Living Things as a Hobby."

Careers for You

There may be a future for you in many lines of conservation work:

1. As an *entomologist* to find out how to control insect pests.
2. As a *forester* or *forest ranger* to work in state or national forests. Some universities have a college of forestry to train people for these positions.
3. As a *naturalist* in wildlife sanctuaries to help people enjoy and learn about plants and animals found there.
4. As a *teacher* of the biological sciences in a high school or college.

Living Things as a hobby

Why not take a field trip this spring or summer? See for yourself many of the different kinds of living things about you. You may want to collect some animals and plants for classroom, laboratory, or museum.

Invite a few friends to go with you. Take jars of various sizes, a dip net, and a metal can in which you can store plants so that they will keep fresh and moist. If you have an old pillowcase or a burlap bag, take that, too. You may come across some harmless snakes you will want to have for the school museum. Be sure to take a notebook. And, of course, take a good lunch and a first-aid kit.

Probably you will find a pond. As you approach it, you may hear soft "plops" as frogs jump into the water. Look for sunfish, which are found in the shadows of rocks. Catch some with your net, for sunfish are fine for the school aquarium. Also take some of the water plants to stock the aquarium.

Classifying an Animal

How do you know sunfish are fish? Most fish have fins, gills, and scales. Reptiles, such as snakes, turtles, and lizards, have scales, too. However, reptiles have no gills and fins. You can come to know a good many animals by grouping those which have the same characteristics. When a scientist places living things with similar characteristics in one group, he is *classifying* them. For instance, all animals with fins, gills, and scales are classified in one group as *fishes*, and all animals with feathers are classified as *birds*.

Naming Plants and Animals

It is both useful and satisfying to know the names of the animals and plants you come upon. Just knowing that a plant is a fern or moss does not satisfy you. You want to know which fern or moss it is. Knowing that a feathered creature is a bird is not enough. Which is it? Robin, bobolink, kingbird, or yellow-throated vireo? Which frog is it? Bullfrog, grass frog, pickerel frog, or spring peeper?

In the eighteenth century, Carolus Linnaeus (kar-oh-lus · lih-NAY-us) and his friend Peter Artedi (ahr-TEH-dee) set about giving each animal and plant two names. The two names tell what kind, or *species*, of animal or plant any specimen is. Their system is a very useful one, as you will see.

Where you live, do you find bitterweed, wild tansy, hayweed, hogweed, wormwood, stammerwort, or carrotweed? These are names for ragweed in different parts of the country.

Linnaeus and Artedi gave two Latin names to each living thing.

JULIUS FANTA

228 Learning about living things. *Project:* With your teacher's help, organize a group (in class) or a club, to take field trips regularly. Collect specimens and bring them to class.

Since Latin is no longer a common spoken language, its words are no longer changing form or meaning. Therefore, a Latin name used now will not change and will be recognized by scientists everywhere. One common ragweed is *Ambrosia trifida*. People who are familiar with the system of Linnaeus will know what we are talking about, whether they are in England or Brazil.

Suppose you learned the name of just one new living thing each week. In a year you would know more than fifty! In several years you would be an expert on the living things in your area. At the end of this hobby section, you will find titles of books which describe the habits and give the names of many living things you will find in your surroundings. Why not start learning their names now?

We are going to help you learn the scientific way to classify and name plants and animals. On the following pages you will find descriptions of the major groups of plants and animals. With them are drawings of some important members of each group. These drawings will help you recognize some of the living things which belong to the group. After all, the living things in any one group are similar to each other in many ways. *The numbers given after each of the descriptions on pp. 429–32 show which books in the following reading list will give you the most information about the group.* Why not start a class museum with examples of animals and plants which can be easily collected and shown?

Starting and Keeping a Microaquarium

Perhaps you have visited an aquarium, with its aquatic life. In a salt water (marine) aquarium you will find starfishes to sharks, squid and octopus; and in the largest ones, you may even find mammals such as the porpoise, or a small whale.

But you can have an aquarium at home or at school. One of the most interesting is a microaquarium where you would collect and maintain microscopic animals. Collecting microscopic animals is easy enough and maintaining them is not as difficult as you might think. You will need pint, quart, or gallon bottles; quart jars with some kinds of covers or corks — and, of course, a microscope, slides, and medicine droppers to examine them.

In spring, summer, and autumn go out on a field trip to the nearest pond and collect some of the pond water in your pint jars. To this pond water add some of the mud from the pond (near the shore) and a few water weeds — if you can. At the same time collect some clear pond water in your quart or gallon bottles. Get enough of this so that you won't have to make frequent trips to the pond — unless you want to.

When you come home, or to school, place your pint jars in a cool place, where they will get some light. Under no circumstances place the jars in sunlight or over a radiator; heat generally kills the microscopic plants and animals.

Pour the contents from a pint jar into a quart jar. Now add five rice grains or wheat grains and let stand for two or three days. Add enough fresh pond water from your pint bottles to fill the quart jar three-quarters full. Add five more grains of wheat or rice.

After a few days, microscopic animals will begin to appear; the water may even become cloudy with them. Depending on which ones you originally collected, you may get such protozoa as *Paramecium*, *Stentor*, and *Vorticella*. You will find these pictured and described in reference 1. They will generally feed on the bacteria that feed on the rice or wheat grains. If there is enough light where the jars are kept, you may even get some algae like the desmids, which you will find pictured and described in references 1 and 10. You will find a microscopic zoo and botanic garden in your jars.

To keep your microaquaria (micro for small) going, you will have to divide them every month or so. To do this, take your quart aquarium and divide it equally into two quart jars and add fresh pond water up to the three-quarter mark. Of course, how many aquaria you wish to keep depends on the space you have and the time you wish to spend studying the microscopic animals.

Two boys and one girl we knew began their careers as biologists this way. One of them purchased Kudo's *Protozoology* [1] (a very valuable reference which identifies most of the protozoa you will come across), and is now a protozoologist.

The major problem seems to be in obtaining a microscope. At first you will need to use the school's microscope. Later, with your own money, you will be able to have your own.

Perhaps microscopy or protozoology is for you. Try it.

[1] *Protozoology* by Richard Kudo, 4th edition, C. C. Thomas, Springfield, Ill., 1954.

Reading for the Amateur Naturalist

1. *Field Book of Ponds and Streams* by Ann Morgan, Putnam, 1930.

2. *How to Know the Mosses and Liverworts* by Henry Conard and W. C. Brown, Dubuque, Iowa, 1956.

3. *A Field Guide to the Ferns and Their Related Families* by Boughton Cobb, Houghton, Boston, 1956.

4. *Beginner's Guide to Wild Flowers* by Ethel H. Hausman, Putnam, 1955.

5. *Field Book of American Wild Flowers* by N. Taylor, 4th edition, Putnam, New York, 1955.

6. *American Wild Flowers* by H. Moldenke, Van Nostrand, Princeton, N.J., 1949.

7. *Illustrated Guide to Trees and Shrubs* by Arthur H. Graves, Harper, New York, 1956.

8. *A Field Guide to the Trees and Shrubs* by George A. Petrides, Houghton, Boston, 1958.

9. *Field Book of Common Mushrooms* by William S. Thomas, new rev. edition, Putnam, 1948.

10. *Field Book of Nature Activities* by William Hillcourt, Putnam, 1950.

11. *Hammond's Illustrated Nature Atlas* by Emil L. Jordan, Hammond, New York, 1955.

12. *American Seashells* by R. Tucker Abbott, Van Nostrand, 120 Alexander St., Princeton, N.J., 1954.

13. *Field Guide to the Butterflies* by Alexander B. Klots, Houghton, Boston, 1951.

14. *The Insect Guide* by Ralph B. Swain, Doubleday, 1948.

15. *Insects* by Herbert S. Zim and Clarence Z. Cottam, Simon and Schuster, 1951.

16. *Marine Fishes of the Atlantic Coast* by Charles M. Breder, Jr., Putnam, 1929.

17. *Handbook of Frogs and Toads of the United States and Canada* by Albert H. Wright and Anna Wright, Comstock (Cornell), Ithaca, N.Y., 1949.

18. *Reptiles of the World* by Raymond L. Ditmars, Imperial Edition, Macmillan, New York, 1946.

19. *A Field Guide to the Amphibia and Reptiles* by G. Netting and G. Orton, Houghton, Boston, 1950.

20. *How to Know the Birds* by Roger T. Peterson, Houghton, Boston, 1948; (also Mentor).

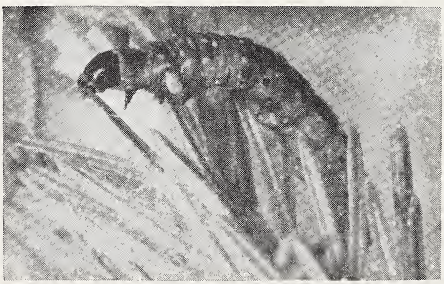
21. *A Field Guide to the Birds* by Roger T. Peterson, Houghton, Boston, 1947.

22. *Bird Songs of Dooryard, Field and Forest*, 3 vols., 33⅓ rpm; Ficker Records, 27 Arcadia Rd., Old Greenwich, Conn.

23. *A Field Guide to the Mammals* by William H. Burt and R. P. Grossenheider, Houghton, Boston, 1952.

24. *How to Know the American Mammals* by Ivan T. Sanderson, Mentor, New York, 1955.

25. *Mammals* by Herbert S. Zim and Donald F. Hoffmeister, Simon and Schuster, New York, 1955.

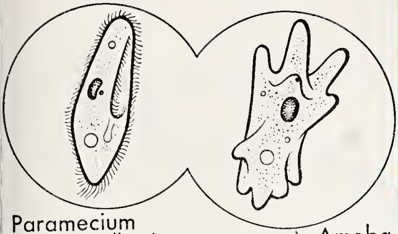


NEW BRUNSWICK INTERNATIONAL PAPER CO.

229 This spruce budworm eats our spruce trees, causing some damage to them. *Project:* Collect, mount, and exhibit harmful insects found in your community.

Animal Kingdom

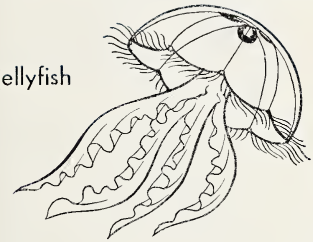
INVERTEBRATE ANIMALS (*Animals Without Backbones*)



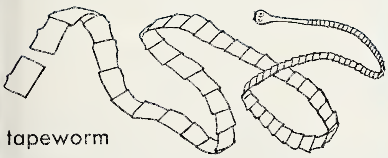
Single-celled animals. In this first group you will find microscopic animals made up of one cell.

Some single-celled animals, like Paramecium, move about by means of tiny hairlike structures. Others, like Ameba, send out projections of the body and seem just to flow along (1, 10, 11).

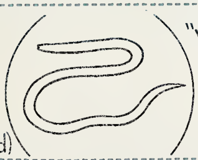
Sponges. At home you have probably used the common bath sponge (not the artificial rubber sponge). This bath sponge is the skeleton of an animal which lives on the bottom of the ocean. It takes in food through pores in the body (1, 10, 11).



Cup animals. These strange animals are generally shaped like a cup or umbrella. The jellyfish and sea anemones belong here. Most of the animals in this group are to be found living in the ocean. The animals have batteries of stinging cells in their waving, armlike tentacles. When a small animal touches these tentacles, it is paralyzed by the stinging cells. It can then be eaten by the cup animal (1, 10, 11).



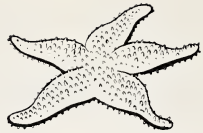
Flatworms. The worms in this group are what their group name states — flat. The tapeworm and liver fluke, both of which infect man, are in this group. The worm Planaria, commonly found in streams, is also a member of this group (1, 10, 11).



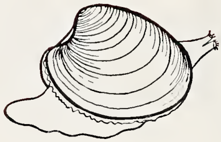
Roundworms. These are the smooth round worms like the common "vinegar eel" (found in vinegar) and the common horsehair worm. The hookworm and trichina are also roundworms (1, 10, 11).

Ringed worms. The very common earthworm and the sandworm belong to this group. The animals of this group have bodies which seem to be made of rings or segments. However, do not mistake a millipede for a ringed worm. Ringed worms have no legs like the millipede (1, 10, 11).

Spiny-skinned animals. To be found in this group are the starfish, sea urchin, and sand dollar. All of these animals have a spiny skin or a hard outer shell (1, 10, 11).



Soft-bodied shelled animals. In this group you will find the oyster, clam, snail, slug, squid, and octopus. Most of the animals in this group have two shells, like the clam, or a spiral shell, like the snail. The squid and octopus have a straight shell inside the body (1, 10, 12).



Joint-legged animals. This is the group that has the greatest number of animals. All of them have legs made up of joints. In this group are:

Crabs, lobsters, and their relatives (with five pairs of legs).

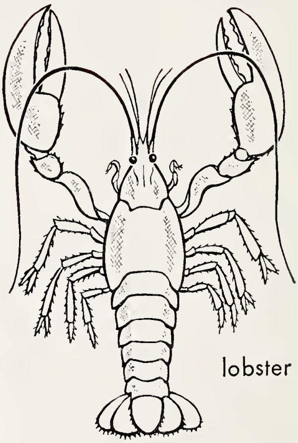
Centipedes and millipedes, with many legs.

Insects, with three pairs of legs. Most insects have wings.

Spiders, with four pairs of legs and no wings (10, 11, 14, 15).

All the animals in these groups are very different from you. They have no internal skeleton and no spinal cord. They are called invertebrates.

You, and such animals as birds and lions, have internal skeletons and belong to the next group, the vertebrates.



VERTEBRATE ANIMALS

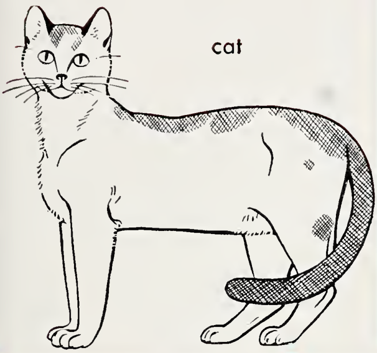
Although all the vertebrates belong to one group, they are classified into several subgroups. For example:

The fishes. These are very common animals with scales and fins. As you know, they live in water (1, 16).

The amphibians. Frogs and salamanders belong to this group. The adults generally live on land but lay their eggs in water. The young live in the water until they become adults (1, 10, 11, 17).

The reptiles. Animals like snakes, turtles, lizards, alligators, and crocodiles belong to this group. These animals have scales, and most of them lay eggs with shells (10, 11, 18, 19).

The birds. These animals that fly are warm-blooded and have feathers and wings. They lay eggs with shells (20, 21, 22).



The mammals. You will find the furred warm-blooded animals are among this group. In most mammals, microscopic eggs develop into young within the mother's body. The young are fed milk from mammary glands. The mammals also give their young great care.

Within the mammal group are such strange animals as the duckbill, or platypus, which unlike other mammals lays hard-shelled eggs outside its body. However, it suckles its young like other mammals.

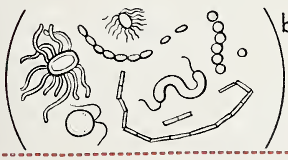
You, of course, are a mammal (10, 11, 23, 24, 25).

Plant Kingdom

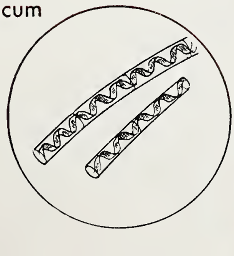
You can learn the names of plants in much the same way as the names of animals. In this book, we are going to classify all plants into five major groups.[1]

The five groups include some 350,000 kinds of plants. The various groups of animals include almost one million different kinds. Where you live, however, there is only a small number of different animals and plants. Once you know the common plants and animals, you will find it easy to identify others as you find them.

The five major groups of plants are:



Bacteria. In this group are microscopic, colorless, single-celled plants. Most of the bacteria are harmless, some are helpful, and some cause disease (Chapter 5).



Simple-bodied plants. These very common plants have no roots, stems, or leaves. They are the common pond scums — soft, green masses sometimes found floating on the surface of ponds or streams. In a jar of water, a mass of these plants looks like a mass of fine, soft green hair.

[1] As you go on in your study of biology, you will find that some scientists group the plants into four groups, and others group them into five. For beginners, however, we think it better to group the plants into five groups.

In this group also are the colorless plants, the fungi. *Colorless* here means "lacking chlorophyll." Some fungi are blue, yellow, or red. The fungi include the mushrooms, bread molds, and blue molds (1, 9, 10, and Chapter 18).

The mosses. The common green-colored mosses are small plants which live where it is moist. There are two kinds of mosses. Some mosses, called liverworts, have flat bodies. Others have upright leafy bodies (like those in the drawing). All produce spores in a structure which looks like a tiny golf club. Spores are microscopic cells which reproduce the plant (2, 10).

The ferns. You will find most of these plants easy to recognize by their leaves, or fronds, shown in the drawing. At certain times, the backs of the fronds produce spores. Ferns have underground stems and roots (3, 10).

Club mosses and horsetails also are classified as ferns.

The seed plants. The seed plants are the common plants you see everywhere about you. They generally produce flowers and seeds. Oaks, maples, oats, wheat, and corn all belong to this group. Other members of this group are the pines, hemlocks, and spruces.

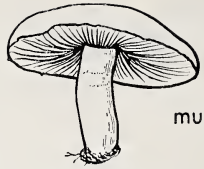
There are several subgroups. The two most important are:

Plants with flowers. The flowers may be small, as in the grasses, or large, as in the lily or magnolia.

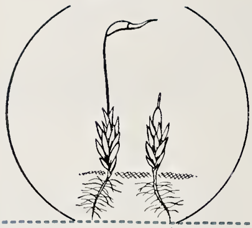
Plants with cones. These are the plants with needle-shaped leaves, like the fir, pine, and spruce. Their seeds are found in cones (5, 6, 7, 8).

You are on your way. This is the simple way in which the writers of this book began. It is the way many an expert on plants and animals began.

Ask your teacher's help in your study. Also get several of the reference books. In any event, if you begin this hobby now, you should be an accomplished naturalist when you leave high school.

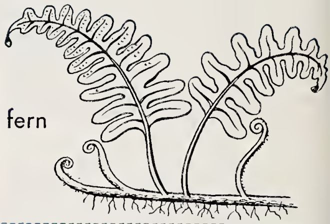


mushroom



moss

fern



wild strawberry

spruce

THE FROG

In its tadpole stage, the frog lives in water and breathes through gills; but as an adult it lives on land and breathes through lungs.

Photo of green frog above by Bernard L. Gluck from National Audubon Society.
Artwork by CARU Studios, Inc., New York City, adapted by permission from EXPLORING BIOLOGY: Fifth Edition by Ella Thea Smith.

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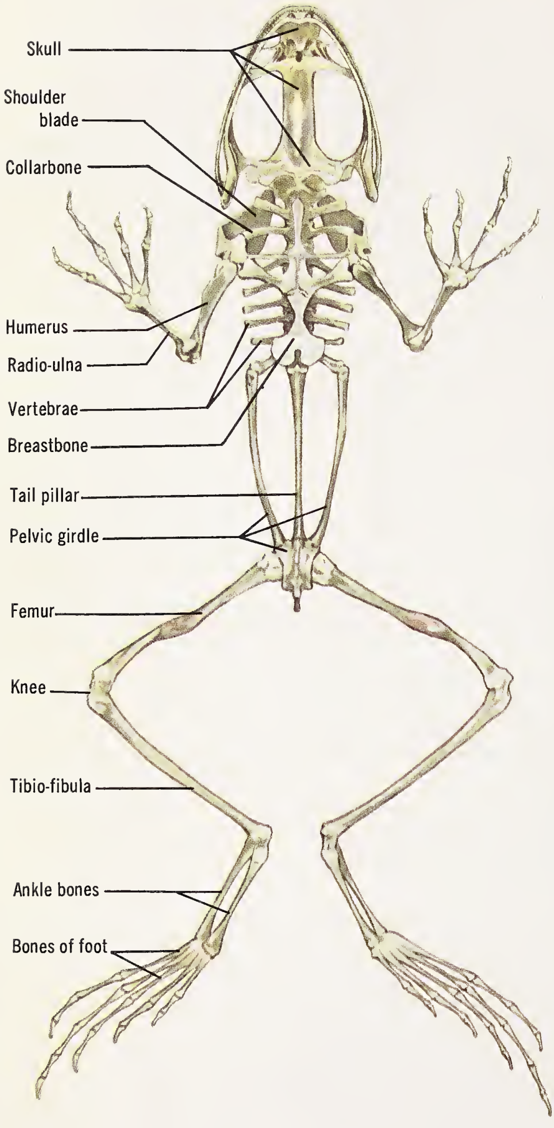


THE BONES AND WHAT THEY DO

The bony framework of the frog's body is its skeleton, viewed here from beneath the body and (below) as it would look if the frog were in a normal sitting position.

The skull, spinal column, collarbones, shoulder blades, breastbone, and pelvic girdle help to protect from injury such organs as the brain, spinal cord, heart, lungs, and digestive organs. In addition, these skeletal parts, acted upon by skeletal muscles (see facing page), give support to the head and trunk of the body *without* making them immovable. Complete inability to move the bones would be disastrous to the frog; movable joints are an important feature of its skeleton.

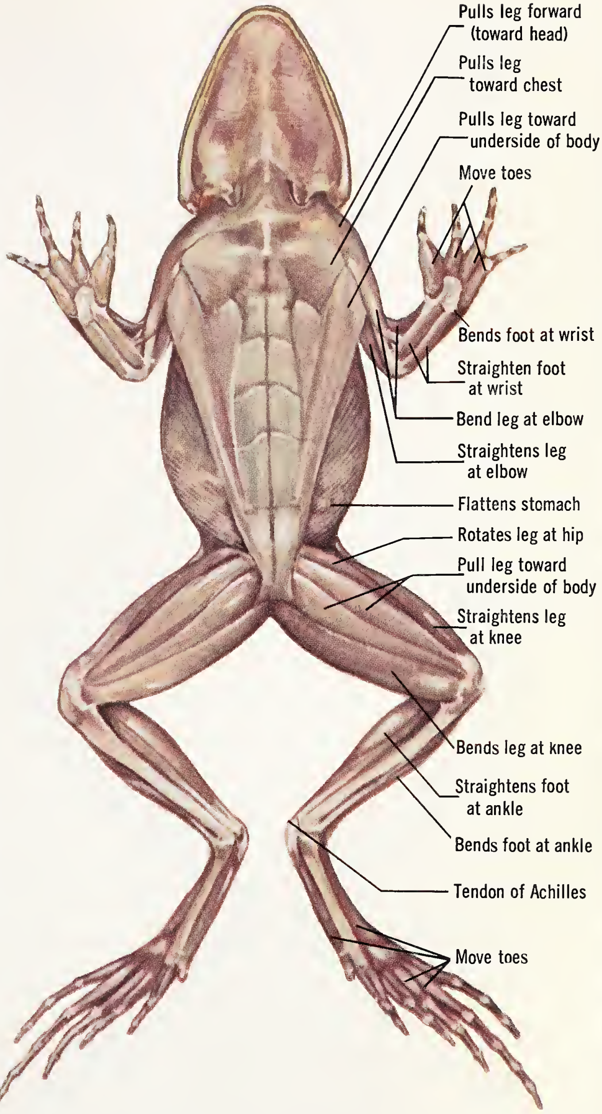
The leg and foot bones, with the pelvic girdle and the bones of the shoulder, are the parts of the skeleton that most enable the frog to move about (the jointed spinal column also moves, but very little in proportion to the freedom of the four legs). The bones act somewhat like levers acted upon by the skeletal muscles; as a result the frog is able to leap on land and swim well in water.

The frog's backbone has only a few vertebrae, nine in all. In this and in other respects the frog's skeleton is different from the skeletons of other vertebrates with other ways of life.

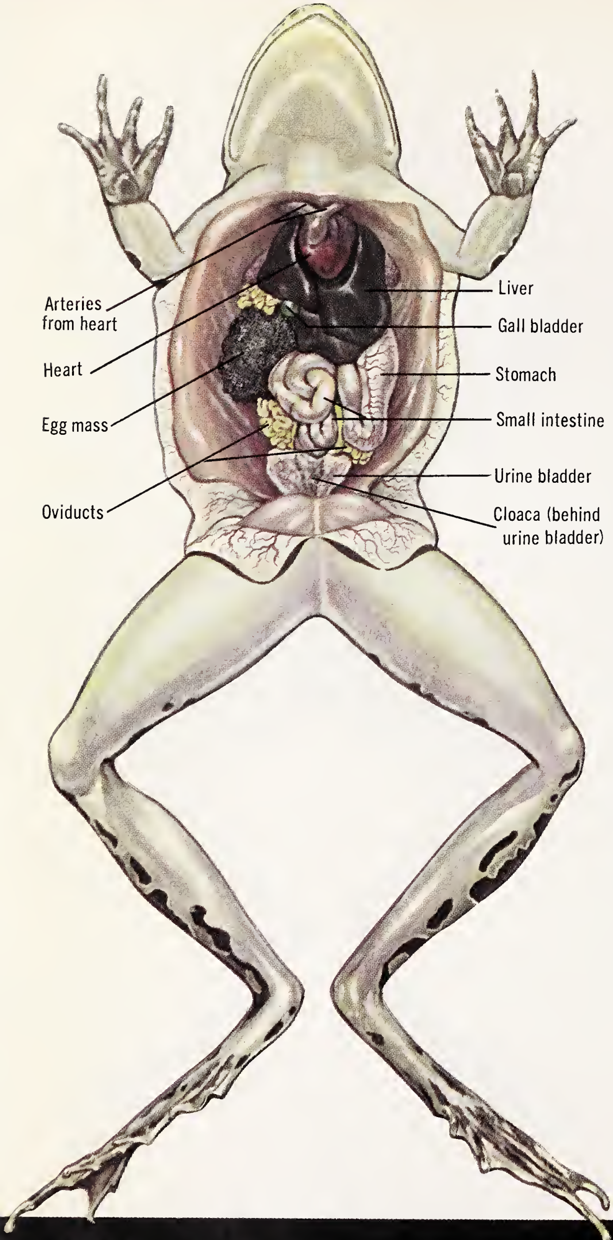
HOW THE FROG MOVES The system illustrated is the skeletal muscular system after removal of the skin; that is, these are the muscles which are attached to bones, with a few exceptions. The muscles that would be seen, viewing the frog from underneath, are shown at the right; those that would be seen if the same frog were in a sitting position are shown below.

The skeletal muscles are also called *voluntary* muscles because they are used for movements over which the frog normally has control. Usually these muscles work in pairs. When one muscle of a pair of leg muscles contracts, the leg is bent. When the other muscle of the pair contracts, the leg is straightened again. Other muscle pairs allow the frog to twist or rotate a part, first in one direction, and then back again.

Skeletal muscles normally are attached to bones by tendons, and the two ends of each muscle are attached to different bones. The tendon at one end of a muscle usually runs across a joint—for example, the knee—and is attached to the bone on the other side of that joint. When a muscle contracts, one bone to which it is attached serves as an anchor, and the other bone (sometimes more than one) is made to move. In this way, skeletal muscles and the bones of the skeleton work together.



FROG CHART 3—THE INTERNAL ORGANS



DISSECTION VIEW If you dissect an anesthetized or a preserved frog, you will be able to see the organs labeled above. For example, you see the heart, the main organ of circulation; the stomach, intestines, and other organs of digestion; and the egg mass in a female frog. At the right are the stages of the frog's growth from egg to tadpole to adult frog.

Investigating the Life of the Frog

1. *Investigating development.* If you live where there is a pond or a stream, you may be able to collect frog's eggs or eggs of the frog's relatives, the toad or salamander. These are to be collected just after they are laid — in early spring. Bring them to the laboratory in a jar containing the water in which they have been laid. Follow the development of the frog as pictured on pp. 394–395.

2. *An investigation into the physiology of the frog.* As soon as the tadpoles have hatched, divide them into five equal batches in jars of pond water. (You will need to keep supplies of pond water on hand; collect a gallon jar of it whenever you can. Collect water weeds as well.)

a. In a half quart of water in each jar, place four tadpoles. Feed one group the pond weeds; place a few sprigs in the jar. As the weeds are eaten, replace remnants with fresh ones.

b. Feed another batch fresh lettuce. Replace the food with fresh lettuce daily.

c. Feed a third batch as in *b*. But add one drop of iodine to the water each day.

d. Feed a fourth batch bits of cooked beef liver. (Be careful not to add more than the tadpoles can eat in a day. A piece of liver about the size of a pat of butter is sufficient. Keep a supply of liver in the refrigerator.)

e. Feed a fifth batch as in *a*. Except to this jar add one drop of iodine to the water each day.

Keep careful records. Which of the batches of tadpoles develops fastest? A clue to the development is this: Carefully examine the diagrams on pp. 394–395. What happens to the tail of the tadpole? Biologists call the process by which the tadpole's tail is lost *resorption* (re-SORP-shun). The faster a tadpole develops, the faster its tail is resorbed.

You may also want to find out the effect of iodine in this experiment. Does it hold back or speed up development? Why? *Clue 1:* The substance produced by the thyroid gland has iodine in it. *Clue 2:* You will find out more about the work of the thyroid gland in a textbook on biology or physiology.

3. *Investigating the anatomy of the frog.* You will want to investigate the structure of the frog, as well as its development and physiology.

Your teacher may have preserved frogs, or you may order them from a biological supply house. Or you may collect one. (Before dissection, live frogs should be anesthetized under the supervision of the teacher.) You will need also a dissecting pan (or a long piece of cork board or soft wood), a sharp scissors, a forceps (or tweezers), and about a dozen pins. Before you begin, read the following.

Place the frog on its back. Make a sharp snip in the skin just above where the legs join the body. Now cut the skin in one straight line along the center up toward its head. Be sure to point the scissors up or you will cut into the body wall. After you have made this long cut in the skin, cut the skin towards the arms to make a flap. Make the same cuts at the legs. The result will be that you will have two flaps of skin which you can pull away from the body. Pin these flaps down (with your pins) to the wax of the dissecting pan, or to the cork or wood board.

Now do the same to the body wall. This is thicker than the skin but a similar flap can be made. Use the same pins to pin the frog down. Now the inner organs are exposed as in Frog Chart 3.

Identify each organ, using Chart 3 to help you. Lift — do not cut — away the organs which are on top. In this way you can begin to study the frog's anatomy.

To study the brain, you will have to cut away the skin of the head and chip off the soft bone covering the brain with your forceps. Be patient.

If you need to stop your dissection and hold the frog for some other hour of work be certain to wrap the preserved frog in several layers of wet paper. Live frogs which have been anesthetized may be preserved in 70% alcohol, or kept in a refrigerator overnight.

UNIT 7

Doing the World's Work

If you had lived a hundred and fifty years ago, you would have had to do many things by hand. There were few machines then, and those that did exist were clumsy and not very efficient. Today we push a button for electric lighting, we travel on land and sea and in the air by fast trains, ships, and planes. Rocket engines propel satellites into space. Complicated typesetting machines and high-speed presses turn out books, magazines, and newspapers.

The simple machines of a century and a half ago are still used for many simple jobs, but levers, wheels, gears, axles, and pistons are now combined into more complex machines which multiply a small force many times. Engines may wear out but they do not tire as muscles do. As long as energy, produced by water power or fuels, is put into a motor or engine, the engine will keep on working. This unit is the story of man's quest for new sources of energy to power new engines to do more work in shorter time.

Your Science Inventory

How much do you already know about doing the world's work? Check your answers when you finish this unit to see how many you had right. In your notebook match the items in List B with the kinds of energy listed in List A. DO NOT MARK THIS BOOK.

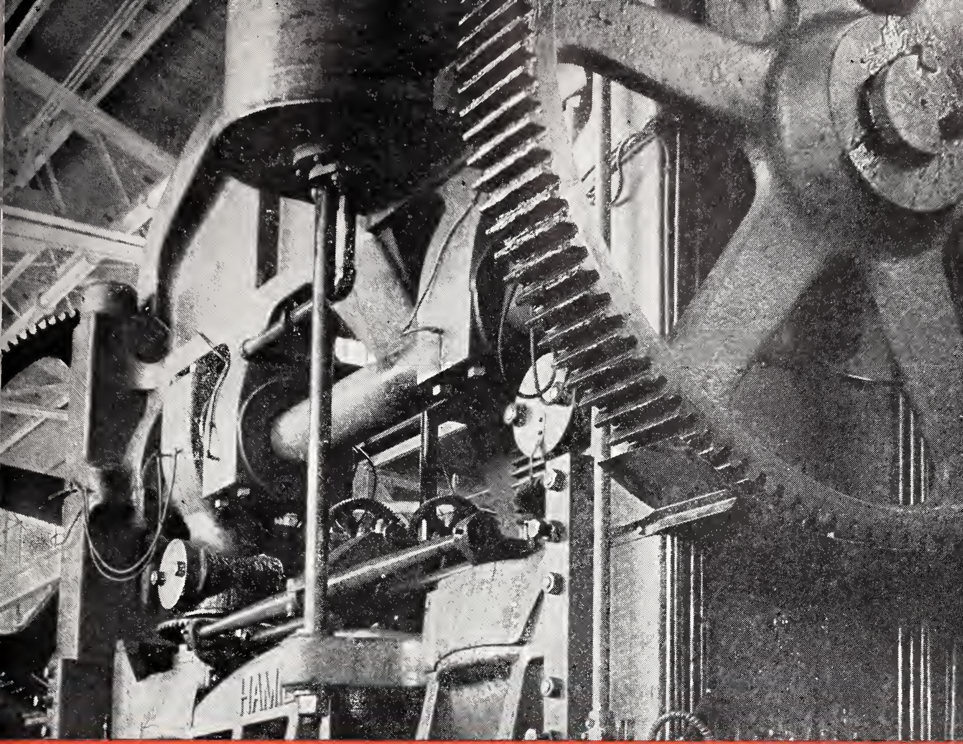
List A	*List B*
1 chemical energy	a dynamite
2 energy of motion	b flight of an arrow
3 heat	c food-making in plants
4 light	d steam engine
5 ultraviolet rays	e sunburn

In your notebook write your best answer:

6 A boy weighing 100 pounds walked up six flights of stairs. The distance between floors was 20 feet. The number of foot-pounds of work he did was (a) 200, (b) 2,000, (c) 1,200, (d) 12,000.

7 The material with the highest kindling temperature is (a) coal, (b) a match head, (c) dry paper, (d) dry wood.

8 The material with the highest heat value per unit of weight is (a) dry wood, (b) coal, (c) gasoline, (d) water.



9 When you brush your hair on a cold, dry day, the crackling sounds you may hear are the result of (a) an electric current, (b) static electricity, (c) magnetism, (d) your imagination.

10 Lightning is (a) a kind of electric spark, (b) a fire in the sky, (c) the result of thunder, (d) usually harmful.

11 You can easily magnetize (a) copper, (b) gold, (c) iron, (d) zinc.

12 If you connect three dry cells, each marked 1.5 volts, in series with a voltmeter, the voltmeter will read (a) 0.5 volt, (b) 1.5 volts, (c) 3 volts, (d) 4.5 volts.

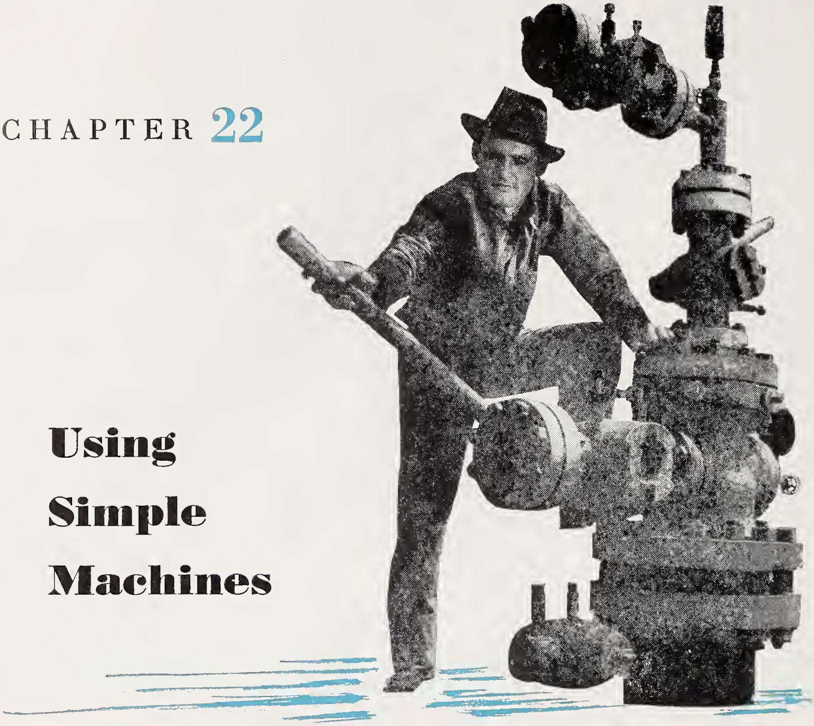
13 To cover a copper dish with a very thin layer of silver, one thing you would use is (a) an electric current, (b) heat, (c) pressure, (d) static electricity.

14 When an airplane banks, (a) the back of the plane is higher, (b) the front of the plane is higher, (c) one wing is lower, (d) the landing gear is down.

15 The aircraft engine with the fewest parts is (a) one with only a few cylinders, (b) the ram jet, (c) the turbo-jet, (d) the turbo-prop jet.

CHAPTER 22

Using Simple Machines



You can easily lift a weight ten times your own (or more). How? You use simple machines. You use your arm, a hammer, the gears on your bicycle. Each simple machine helps to multiply your muscle many times.

Has a tire ever gone flat when you were riding in the family car? This may happen to anybody. It happened to Mr. Doe and his son one day while they were driving down a country road. It was just then that Mr. Doe remembered that he had no jack in the car; he had loaned it to a neighbor the day before. There was a long fence rail and a stone wall nearby, and Mr. Doe was resourceful.

He placed a large stone underneath the rear bumper. He then put one end of the fence rail over the stone and underneath the rear axle of the car (Fig. 230). He pushed down on the other end of the rail and easily lifted the car while his son built up a support for the axle with the other stones. The tire was soon changed, the stones and fence rail put back, and everyone was happy.

Mr. Doe used a fence rail to lift his car. Scientists have a special name for any tool that helps a person do *work*. It is called a "machine." Thus the fence rail that Mr. Doe used was really a *simple machine*.

Mr. Doe couldn't lift the rear of the car by himself. His muscles couldn't

make enough force — enough of a push or a pull — to lift that weight. But with the aid of a *simple machine* he did something that he couldn't do by himself.

You may never have lifted the end of an auto with a fence rail, but you have certainly used simple machines to help you do work. And you have certainly seen many simple machines at work all around you.

In this chapter you will see how these simple machines work — and you will begin to understand how important machines are in our everyday lives, helping us to do work.

CONTROLLING ENERGY

Have you ever heard someone say, "Oh, I just haven't got the energy to do that," or "I feel full of energy today"? To do work you must have energy, of course. And the same is true of a machine: To do work, a machine must be supplied with energy.

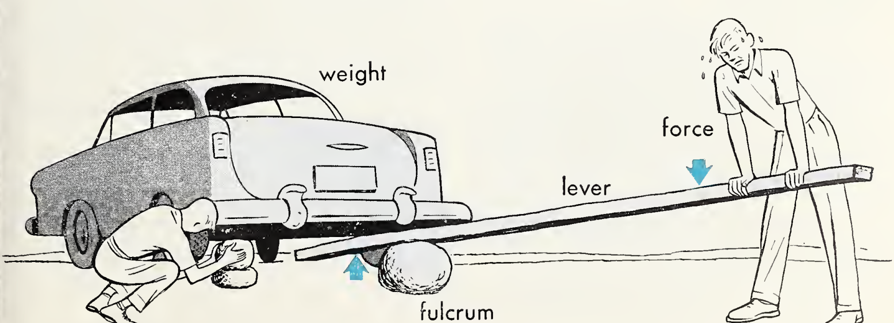
What Is Energy?

No one has ever really defined *energy* to everyone's satisfaction. Here is one way of describing what energy is: Anything that is able to move itself or to make other things move has energy. You are able to run and play football, basketball, and other games because you get energy from the meals you eat. All living things store up food energy. Coal yields energy to heat homes and run factories. Gasoline gives the energy to run automobiles and fly airplanes. Falling water has the energy to make electricity; dynamite has the energy to blast rocks; and uranium 235, plutonium, and hydrogen, as used in atomic energy, have the greatest energy man has been able to produce. Wind has the energy to move sailboats and, during hurricanes and tornadoes, to destroy homes; an avalanche has the energy to uproot trees and move rocks; and a rocket has the stored energy to rise hundreds of miles above the earth's surface, perhaps even to travel into space. So it goes — you can give many other examples of energy in things that move or have power to move other things.

Scientists have names for different kinds of energy. Let's see what they are, so that we can keep our thinking about energy straight.

Often an object may appear to have no energy at all, but it may really have a great deal of stored-up energy. Stored-up energy is energy

 Compare what Mr. Doe is doing with your experiment on page 442.



not in use but able to be used at a later time. Water just at the top of a waterfall has stored-up energy because of its position. This stored-up energy changes into energy of motion as the water falls. This energy of motion [1] in falling water turns turbines at the base of large dams, and the moving turbines make electricity. In the same way, an archer stores up energy in his bent bow. As he releases the string, the stored-up energy of the bow is changed to energy of motion. Thus energy of motion is given to the arrow. This energy of motion is called *mechanical* energy.

Dynamite, gunpowder, coal, and gasoline, together with other explosives and fuels, have stored-up energy because of what they are made of, that is, because of their chemical nature. This kind of stored-up energy is often called *chemical* energy. Coal or other substances that have stored-up chemical energy give it off in the form of *heat* energy. Waves that travel through space, such as light, radio, ultraviolet, radium, and X rays, have the kind of energy called *radiant* energy. But all the kinds of energy we have named are merely one or the other of the two main kinds of energy — stored-up energy, and the energy of motion.

Where Does Energy Come From?

If you were asked to tell where energy comes from, what would you say? You might say from coal, oil, food, the earth — and you would be perfectly right. Yet all the energy that has practical uses in this world of ours comes from the sun.

It is the sun's radiant energy that warms the earth and causes water to evaporate into the air and later to fall as rain. Radiant energy from the sun causes seeds to grow into plants, for food. You have learned that coal, the greatest single source of energy in the crust of the earth, was formed by pressure upon plants that lived millions of years ago. These plants grew because of the sun's energy. Oil and natural gas were formed by the earth's pressure upon the remains of plants and animals that also lived millions of years ago. Thus coal, oil, and gas really got their stored-up energy from the sun.

Without the sun, there could be little heat or light on the earth. The earth would be a dark, frozen planet. Its temperature would be hundreds of degrees below zero. There would be no life as we know it — none of our plants and animals could exist. Without the sun the real source of our energy would be gone. Even the atoms, whose energy we are just beginning to tap, probably came from the sun when our earth and planets were formed.

Energy Changes Its Form

Rub the palms of your hands together, hard. What you feel when you do this shows something important about energy. The palms of your hands get warm, showing they have *heat energy*. Where has this heat energy come from? From the *mechanical energy* of rubbing your hands together. This is one example of *how energy can change its form*. In this case energy changed from mechanical form to heat form.

Here is a more spectacular demonstration of energy changing its form:

[1] One name for stored-up energy is *potential* (po-TEN-sh'l) energy; for energy of motion, *kinetic* (kih-NET-ik) energy.

Connect a piece of fuse wire between the clips, as in Fig. 231.[1] (*Caution:* Never use house current for this experiment; use only dry cells.) When you push the switch, electricity from the dry cells flows through the fuse wire and causes the fuse wire to melt. Here electrical energy is changed into heat energy. You may see a flash of light as the fuse wire melts. If that happens, you know that some of the *electrical energy* has changed to the form of *light energy* as well as heat energy.

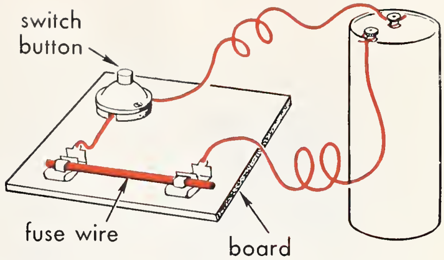
When you press the button of a flashlight, you are changing electrical energy from the battery into both light and heat energy inside the lamp. And inside the battery, at the same time, *chemical energy* is changing into *electrical energy*. In the motor of an automobile the chemical energy of gasoline is changed to heat energy. When you strike a match, the mechanical energy of your moving hand is changed to heat energy by the match head rubbing on the matchbox. This heat energy releases chemical energy in the match head, which turns to heat and light.

Thus energy changes its form. Scientists call this the *transformation of energy*. Sometimes energy is transformed — that is, changed — into heat or light, into sound or electricity. All around you are complex machines and devices to transform energy. Some of these machines transform energy into *force*.

Energy and Force

What does the scientist mean by force? The answer is surprisingly simple. *Force is a push or a pull.* When you turn a page of this book, pulling the page up and over, you are using a force. If you push a stalled car, you are exerting a force (even if the car doesn't budge). When you brush your hair or your teeth, walk, run, sit down, get up, you are using forces: pushes and pulls.

[1] The fuse wire should have a rating of two *amperes* (AM-peers).



231 When electrical energy is changed to heat energy in the fuse wire, the wire melts

As you know, by the end of a fast game of basketball, using forces takes energy. The energy you get from your food makes the forces you use. The energy in steam forces a heavy freight train to a distant city. The energy of gasoline forces a heavy truck up a steep hill. The energy of your body gives force to your bat, which in turn sends a baseball over the wall. Mr. Doe at the beginning of this chapter also used the energy of his muscles to force his car upward with a fence rail. Everyone, every moment of the day, is using force and is seeing force used to do the world's work.

When Do You Work?

You might think that whenever you exert a force you are working. But the scientist wouldn't agree with you. He has a special definition of what work is. He says that *work is done only when a force moves an object.* In other words, if the object doesn't

move, no work is done.[1] Have you ever tried to move a heavy stone or a piano? You may have tired yourself out, but the stone or piano remained unmoved because the force you used was not enough to move it. Since the object didn't move, you have done no work, says the scientist. Let's see why the scientist uses this limited definition of work.

Work is done, says the scientist, *when a force moves an object*. This way of defining work has a great advantage: it allows the scientist to *measure* how much work is done. This is very useful, especially when it comes to understanding machines. Let's see how the scientist measures work, and what comes of it.

Measuring Work

The scientist's way of measuring work is simple. Work is done when a force moves an object. So the scientist measures the *force* used, measures the *distance* the object moves, and multiplies them together to get *work*.

This book you are now reading, for example, weighs about 3 pounds. If you lift it 2 feet in the air, how much work do you do? The *force* needed to lift the book is 3 pounds. The *distance* moved by the object, the book, is 2 feet. Multiplying *force* by *distance* gives 3 times 2, or 6, for the work done. But 6 what? Since we multiplied feet by pounds, the answer is 6 *foot-pounds*. When you lift this 3-pound book 2 feet, you do 6 foot-pounds of work.

Let's take another example. You may have chinned yourself on a bar. You reached above your head and by grasping the bar with both hands pulled yourself up until your chin was over the bar. If you weigh 100 pounds and you lifted yourself two feet, you did 100×2, or 200 foot-pounds of work. But no matter how much energy you used to keep yourself chinned, you did no work while you remained with your chin on the bar. Work is done only when a force has moved an object a certain distance. Multiplying the force used by the distance moved is the scientist's way of measuring work.

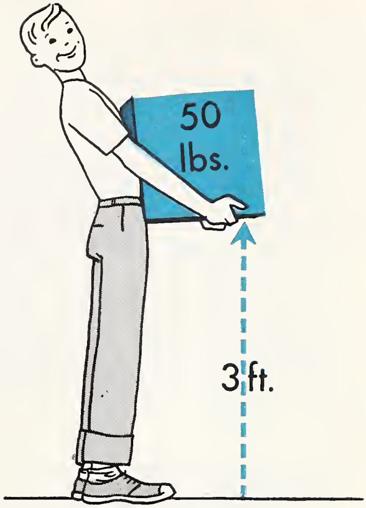
[1] And also, if no force is used, no work is done — even if the object is moving! See *inertia*, a little further on.

Resistance

Sometimes you may try to move a large or heavy object, like a piano, and fail. The object remains unmoved because its *resistance* is greater than your force. What gives the object this resistance to being moved?

Perhaps the *weight* of the object is too great for your force. Weight is due to the force of gravity. This force holds everything to the earth's surface, as you know. To lift a stone you have to use force to pull the weight of the stone upward against the force of gravity.

If you want to push a heavy box to one side, there is another force you must overcome: *friction*. The friction of the box's uneven surface rubbing against the uneven surface of the floor resists your force. Friction in this situation is a force you would like to get rid of. But suppose there were no friction anywhere. You would not be able to take a step. You would find it hard to come to a stop. Every movable thing would slide with you. Unless you grabbed something that was fastened down, or slid into a corner, you would keep on going.



232 Work (in its scientific sense) is done only when an object is moved a certain distance. Is the boy at the left doing any work? Are you now doing any work?

Even without friction, there is something else that resists your force when you try to move an object. It is called *inertia*. Inertia is of two kinds. It is the tendency of an object at rest to remain at rest. It is also the tendency of an object in motion to keep right on going.

Have you ever tried to push a car that has run out of gas? If you have, you almost certainly noticed what inertia does. When you begin to push the car, it takes a lot of force to get it moving. This is because, being at rest, the car tends to remain that way. But once you get the car moving, it doesn't take much force to keep going — because the car in motion tends to keep on moving. Because the car tends to keep moving, it is hard to stop when you reach the gas pump, and you have to apply more force, a pull this time, to overcome the car's inertia. For the same reason an automobile or a train does not stop as soon as the brakes are applied. It keeps moving because of its inertia.

So when you lift or push anything and make it move, you are doing work against the resistance of *gravity*, *friction*, and *inertia*.

Of course it is easier to do work when we make use of a machine, instead of just our muscles. A machine helps us to do tasks that would be beyond our strength without the machine. It also helps us save our strength, and speeds up the jobs we do. Let's see *how* making use of machines helps us.

MAKING USE OF MACHINES

Mr. Doe, you remember, couldn't lift the rear of his car by himself to get at that flat tire. So he called on a

machine to help him: a fence rail. That fence rail was really a simple machine called a *lever*. Of course, you know how to use a lever. You've used levers many times, to pry the lid off a paint can or a tin of shoe polish; to open cans with a can opener; to squeeze oranges; to pry the cap off a bottle — the examples are almost endless. You know *how* to use levers so well that you don't even stop to think about them. But now let's find out *why* this simple machine is so helpful.

How Does a Lever Help Us to Do Work?

For this experiment you need a ruler, an eraser, and a book. Place your finger under the edge of the book and raise it slightly, testing its weight. Now place the end of the ruler over the eraser and underneath the edge of the book. With your finger press down on the other end of the ruler. Can you lift the book more easily with the ruler than with your finger alone? Now move the eraser toward the middle of the ruler and press down on the ruler again. Can you raise the book as easily as before?

The ruler, as you use it, is a lever. It is supported at one point (the eraser). This point of support is called a *fulcrum*. You apply a *force* by pushing down with your finger at one end of the lever. The book, because of its weight, pushes down at the other end of the lever. The weight (of the book) resists the force of your finger. The weight to be lifted is therefore called a *resistance*. When you use levers, there is always a force, a fulcrum, and a resistance. The force acts against the resistance.

Now you can apply this knowledge to your own experiment and to Mr. Doe's experience in Fig. 230.

1. The ruler was a lever. The fulcrum (the eraser) was between the force (the pressure of your finger) and the resistance (the book). Mr. Doe's fence rail was a lever. Can you see the fulcrum, force, and resistance in the fence rail illustration?

2. You found the force you used to push down on the end of the ruler much less than the resistance (weight of the book). That is, you saw that small forces can move heavy objects, and how Mr. Doe was able to lift his car with the fence rail.

3. You noticed that when you moved the eraser (the fulcrum) toward your finger, the force you used to lift the book became greater; that is, you had to push harder. You can see that, in order to lift a heavy object with a little force the fulcrum should be as close as possible to the object (Figs. 230 and 233).

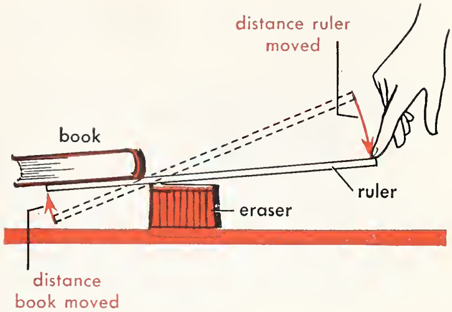
4. With this lever, then, you are able to *multiply the force* that you put in at one end. Thus you are able to lift the book with a small force, which the lever multiplies. And Mr. Doe was able to lift the end of his car. But did you notice that, while this was happening, the *distance* you moved the end of the ruler was much greater than the *distance* the book was raised? And the distance Mr. Doe moved his end of the fence rail-lever was much greater than the distance the car rose?

You are not getting something for nothing.

You put in a small force at one end of your lever. You got out a large force at the other end. But you put

in as well, at your end of the lever, a large distance. You got out a small distance at the other end. You gained in the *force* you put in, but you paid for it with *distance* (Fig. 233).

"Of course!" you may be thinking, as you wiggle your ruler-lever up and down. "That's easy to see. You gain in force — and you pay for it by losing distance." But see now how we can use this easy observation to discover what the machine is really doing.



233 If the book weighs 3 lbs., do you have to push with 3 lbs. of force at the end of the ruler? How does a lever do work?

Back to Work

You with your ruler, Mr. Doe with his (or rather the farmer's) fence rail, did the same thing. You moved a *small force* through a *large distance*, at one end of a lever. And you got out of the other end a *large force* moving through a *small distance*.

Have the words *force* and *distance* rung a bell in your mind? *Force* and *distance* are used by scientists (p. 440) to measure *work*, you remember. Let's look at the *work* you do when using the lever. It will lead us to an important idea, not only about the lever but about machines in general. Keep in mind that when we say *work*, from now on, we are talking about the scientist's idea of work: the force multiplied by the distance the force moves. We are not using the word *work* in the vague and different ways that people do generally.

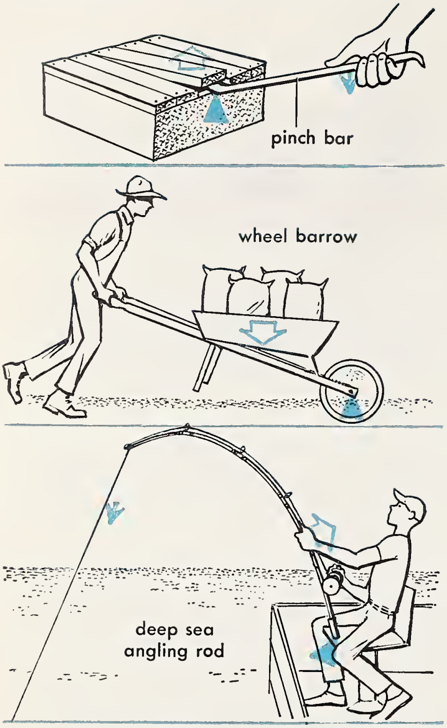
When you press down with your finger on the end of your ruler and raise the book, you are doing work, of course. A small force (from your finger) moves through a large distance (as the end of the ruler goes down).

And at the same time, work is being done at the other end of the ruler. For here a large force (the weight of the book) is being moved through a small distance (as the book rises).

The *work you put in* the lever is: small force × large distance. The *work you get out* is the work done: large force × small distance. You may already have guessed it: *The work put in and the work got out are equal*. With your lever you gain an advantage: you multiply your *force*. But as far as work is concerned, you get out only what you put in. This is true not only of the lever but of other simple machines. It is not only true of simple machines, but true of machines of all kinds. You get out of a machine what work is put into it. This goes for every machine, from a can opener to a space ship.

Take the situation of Mr. Doe with his fence rail and flat tire, for example. Here are some likely figures you would get if you measured things:

- weight of one side of rear end of car, 600 pounds
- force Mr. Doe used, pushing on lever, 100 pounds
- distance Mr. Doe pushed down his end of lever, 6 feet



234 Three kinds of levers. Where is the force applied in each one to make the resistance move through a distance?

distance one side of rear end of car was lifted, 1 foot.

The *work* Mr. Doe put *into* the lever is equal to the *force* he used, multiplied by the *distance* it moved.

work put in = 100 pounds × 6 feet
work put in = 600 foot-pounds

The *work* Mr. Doe got *out* of the lever equals the *force* (or resistance) at the other end of the lever, multiplied by the *distance* it moved.

work got out = 600 pounds × 1 foot
work got out = 600 foot-pounds

As you see, the work put in and the work got out are equal.[1]

Mr. Doe did gain an advantage by using his simple machine, the lever. He multiplied the *force* he used. He made a 100-pound force into a 600-pound force. Scientists call this the *mechanical advantage*. The advantage you got in using the ruler to lift your book is a mechanical advantage. Other simple machines besides the lever give a mechanical advantage too.

No matter how great the mechanical advantage a machine gives you, *the work you put into it equals the work you get out*. So you see, no *work* (as scientists mean it) is saved by the use of a machine. The machine makes the work easier to do, but you still have to do the work. You still have to supply the energy somehow. In fact, this is another way of describing energy. *Energy is the capacity to do work*.

To get only an idea of how many levers we use all the time, study Fig. 234. In each lever illustrated, the fulcrum is located at different points in relation to the force and the resistance. You will now be better able to recognize the many levers *you* use during the day and to see what advantage you gain by using them.

You use other simple machines, too, for making your work easier to do.

The Inclined Plane

Suppose somebody gets on a sled — and you draw the sled up a sloping hill fifty feet high. You will agree that it is certainly much easier to draw

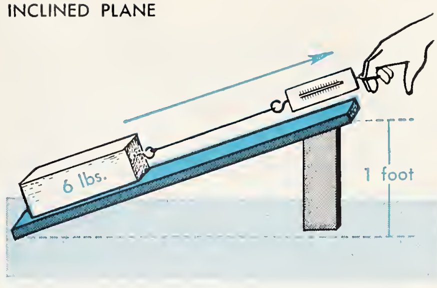
[1] Neglecting friction. You will see what this means later on.

that weight up the long slope than to try to lift it straight up to the same height!

Primitive man found it easier to roll a heavy stone up to his cave, no doubt, than to lift it up to it. The truckman finds it easier to roll a heavy barrel up a sloping surface to the bed of his truck than to lift it vertically. You find it easier to walk up a ramp to your seat high in the football stadium than to climb a ladder to the same height. In each situation an *inclined plane* is being used to make work easier to do — *inclined* meaning sloped or tilted and *plane* meaning surface. The tilted surface must be one of the oldest and simplest of the simple machines!

You can easily check how well the inclined plane eases your work if you try the experiment shown in Fig. 235. To lift the block straight up would take a force of 6 pounds, of course. But with the help of an inclined plane, you can pull the block up to the same height using a much smaller force. However, as you would expect, you make up for the smaller force by moving it through a greater distance. The gentler the slope is, to reach that height, the smaller the force you have to use — but the longer the distance, of course! So here again, as with the lever, *you get out only the work you put in.*

And this is as good a place as any to break the news: Some of the work you get out won't be of much use to you.



235 Lifting the block straight up would result in 6 ft.-lbs. of work. How much work is done to overcome friction?

Squeaks, Groans, Heat

Let us go back to Mr. Doe with his fence rail for just one more demonstration of how that lever behaves. This time, as Mr. Doe presses down and the corner of the car goes up, *listen*. What do you hear? A kind of groan from the fence rail, as the wood bends under the forces at each end. Squeaks, as the car rises and the fulcrum of rock settles into the road. And these sounds tell us that *friction* is at work.

Friction is at work. Things are rubbing against each other. The fibers of wood in the fence rail are being stretched or squeezed as the rail bends. The stone fulcrum is pressing into the wood above it and the ground below it. The end of the fence rail under the bumper is shifting and scraping as it rises. At each point where something *rubs*, there is *friction*. It makes heat. It makes sound, often. It takes *energy*, in any case. So a good share of the work that Mr. Doe puts into the lever is spent on friction. In fact, *some part of the work that you put into any machine is spent to overcome friction.*

Notice however, that this fact does not change the rule that *work output equals input* — no more, no less. We have simply pointed out that some of the work you get out is not the useful work you want to use the machine for. In other words, the work you get out

of any machine is made up of (1) useful work, and (2) useless work, needed to overcome friction.

Of course, friction can often be reduced. Lubricants like oil can put a slippery skin between the rubbing parts. Bearings can cut down friction, like the ball bearings in roller skates, for instance. But friction, unfortunately, can't be done away with completely in a machine. It always takes away some part of the work energy you put in. This being so, let us face the truth about machines: one can never get as much *useful* work out of any machine as is put into it.

Unless, of course, you figure out a way to use the squeaks, groans, rattles, clicks, whirs, thuds — and heat.

Efficiency

The *useful* work out of a machine is always less than the work put into it. You might think this discouraging news for scientists, engineers, inventors; actually it had the opposite effect! For when they understood this fact about machines, they realized what was needed in order to make better machines. So they invented the notion of *efficiency*, to help.

But first a word of warning. Like the word *work*, the word *efficiency* is used by people in everyday speech. People use these words with several different meanings for each one. But when the scientist uses the word *efficiency* — as when he uses the word *work* — he means just one thing whether he is speaking French, Spanish, Russian, Chinese, or English.

Efficiency means comparing the *useful work out* of a machine with the *work put in*. As you know, the useful work got out is always less than the work put in. But machines differ greatly in the amount of useful work they give back when a certain amount of work is put in.

For example, pulling the block up the inclined plane in Fig. 235 may take 8 foot-pounds of work. But apparently only 6 foot-pounds of useful work are done. The other 2 foot-pounds of work put in are needed simply to overcome friction. Since efficiency means comparing useful work out with work put in, you could say that the efficiency of this inclined plane is 6 foot-pounds of useful work for 8 foot-pounds of work put in.

This answer is correct, but somewhat longer than it has to be. The scientist shortens it this way. First, he makes a comparison by writing useful work put out and work put in as a fraction, like this:

$$\text{Efficiency} = \frac{\text{useful work out of machine}}{\text{work put in machine}}$$

(which says, "Efficiency is the useful work of a machine *divided by* the work put in.")

Let's try it, with the inclined plane example:

$$\text{Efficiency} = \frac{\text{useful work out of machine}}{\text{work put in machine}}$$

$$\text{Efficiency} = \frac{6\text{ foot-pounds}}{8\text{ foot-pounds}}$$

$$\text{Efficiency} = \frac{6}{8}.$$

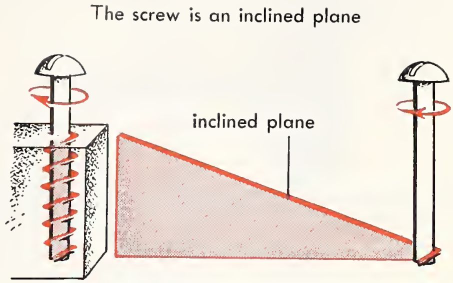
But the scientists do one more thing. They change this to *per cent*.

$$\text{Efficiency} = \frac{6}{8} = 75\%.$$

In other words, the inclined plane in Fig. 235 gives back just 75% of the work put into it, as useful work.

Since the useful work out of a machine is always less than the work put in, you will never get a machine that is 100% efficient.

There are other simple machines that you make use of every day, besides the lever and inclined plane. Let's look further at the simple machines around you.



236 A screw is like a metal bar with an inclined plane wrapped around it. How does the plane work?

The Screw

Have you ever examined a screw carefully? If you have, you must have noted this: a screw is simply a metal rod, with a winding spiral ridge cut in it from top to bottom.

If you could unwind the spiral ridge from a screw, as in Fig. 236, you would see that what you have is really a long, *inclined plane* — wound around a metal rod! As you turn a screw into wood, you are making it slide along the long, inclined plane of its metal ridges. Because the inclined plane is so long for its height, it has a very large mechanical advantage. For this reason, a screw can be used to overcome a great resistance, the friction of wood. It is the friction that holds together two blocks fastened by a screw.

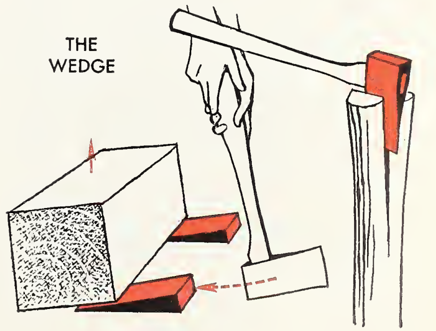
The large jack that can lift hundreds of tons of weight is little more than a big screw with an extra-large mechanical advantage.

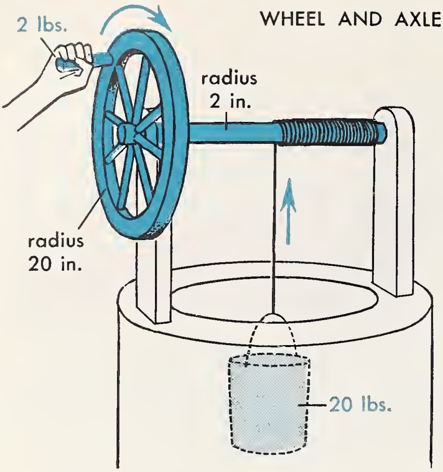
The Wedge Is a Simple Machine

Do you know what a *wedge* is? Examine Fig. 237. In each situation the wedge is thick at one end and tapers to a thin edge at the other end. In fact, the wedge, too, is an inclined plane! But instead of sliding the object up the plane, we force the plane under — or into — the object, when we use a wedge. Thus a small wedge can split a large log if the wedge is the right length and thickness. If the wedge is six inches long and two inches thick at the heavy end, it can be driven six inches into the log to force the end of the log two inches apart. Unless the log is large, this is usually enough to split it in two.

The mechanical advantage of the wedge isn't as large as that of a screw. But you can bring a very large force to bear on the wedge, with a sledgehammer as a lever.

237 Wedges are moving inclined planes used for lifting or splitting.





238 A useful type of lever that can turn through a full circle and keep on moving. The wheel and axle is a lever that spins around the center of the wheel and its axle.

Wheels and Axles

If you have ever hauled up water from a well by means of a windlass like the one shown in Fig. 238, you have used another simple machine called the *wheel and axle.* What is the advantage of this machine? Notice that a force of 2 pounds turning the wheel can raise a resistance weight of 20 pounds. A small force applied to the rim of the *wheel* is multiplied into a large force at the *axle.*

But you don't get something for nothing. As you turn the wheel, your small force at the rim of the wheel travels a long distance. At the same time, the large force at the axle lifts the weight only a short distance. (This happens because the radius of the axle is smaller than the radius of the wheel.)

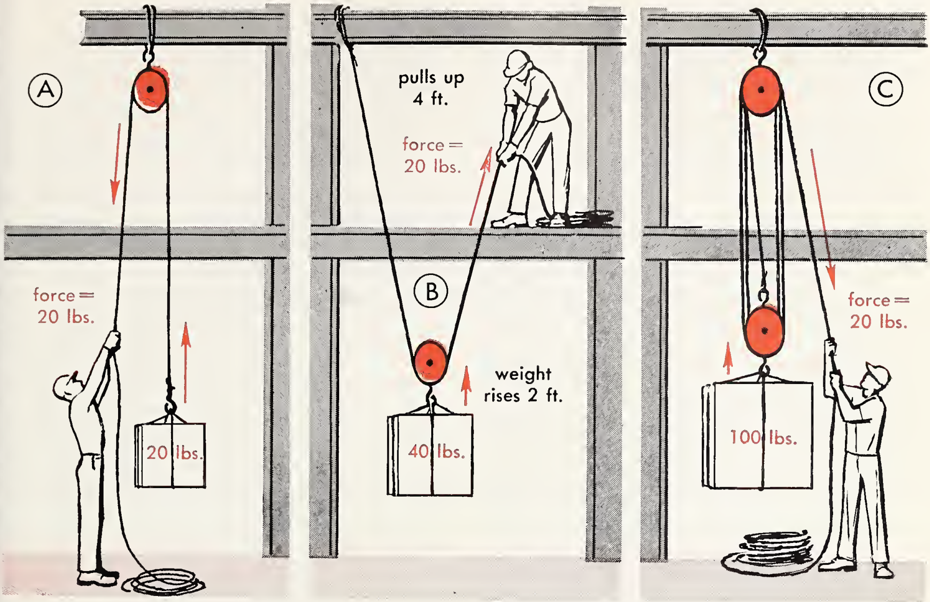
Common examples of this simple machine — the wheel and axle — are the wheel that hoists ladders on fire trucks, the reel that winds up a garden hose, a fishing reel, an automobile steering wheel, the hand brake wheel on top of a freight car, and, yes, even a doorknob.

Pulleys Are Simple Machines

How do you pull up the curtain on the upper half of a school window? How do you pull up a Venetian blind? By pulling *down* on a cord. The cord runs over a *pulley* — a wheel fixed at the top of the window. The pulley changes the direction of your pull, from down to up. You pull down the cord just as far as the curtain or blind goes up. You get no mechanical advantage — that is, your force is not multiplied by the *fixed pulley.* The advantage of the fixed pulley is that it changes the direction of the force you use. It allows you to stand on the ground and lift things far above your head, for example, as in Fig. 239A.

However, there are other pulleys with which you can move heavy weights. The *movable pulley* of the kind shown in Fig. 239B, for instance, gives a mechanical advantage: the man is exerting a force of 20 pounds to lift a weight of 40 pounds. (This is true only when *neglecting friction.* Actually he would have to pull with a bit more force than 20 pounds, to overcome the friction of the pulley.) But notice that he has to pull his end of the rope a distance of 4 feet in order to lift the weight 2 feet.

Sets of pulleys of the kind shown in Fig. 239C are called a *block and tackle.* With a block and tackle extremely heavy weights can be lifted using little force. In other words, a block and tackle can have a large mechanical advantage. Of course,



239 (A) A fixed pulley has no mechanical advantage; it merely changes the direction of force. (B) A movable pulley gives a small mechanical advantage. (C) A block and tackle gives a large mechanical advantage. How can you figure what this advantage is in B and C?

the force has to travel a long distance compared with the weight.

Figuring the Mechanical Advantage

You can see that the force being used by the boy holding the rope in Fig. 239C has been multiplied! There is an easy way to figure the mechanical advantage of a block and tackle like this one. Just count the number of ropes that support the weight directly. Look closely and you will see that there are 5 ropes supporting the weight directly, running from the upper pulleys to the lower one. (The rope in the boy's hand is not supporting the load directly.) Since there are 5 ropes supporting the weight directly, the mechanical advantage of this block and tackle is 5.

This means that the force used by the boy holding the rope is made five times bigger. But this way of figuring mechanical advantage does not take friction into account.

You can easily figure out the mechanical advantage (neglecting friction) of some other simple machines, too.

The *lever:* Divide the distance from the *force* to the *fulcrum* by the distance from the *resistance* to the *fulcrum* (Fig. 233).

The *inclined plane:* Divide the *length* of the plane by its *height* (Fig. 235).

The *wheel and axle:* Divide the *radius of the wheel* by the *radius of the axle* (Fig. 238).

But remember, when you figure out the mechanical advantage in this

way, you are leaving out friction. The actual mechanical advantage, counting friction, will be less. How much less depends on how much friction there is, of course.

Looking Ahead

Now you have seen something of how we multiply our muscles with simple machines; how we use machines to make our work easier to do. These simple machines help us in countless ways, not only separately but together. The crowbar, a kind of lever, is one of the farmer's most useful tools. But a clock is made mainly of many levers and wheels and axles connected together. A bulldozer, a power shovel, a crane, a pencil sharpener all are combinations of simple machines. And if you study more complex machines, such as presses that print books like this one, or airplanes, or pipe organs, you can still find the parts that are the simple machines you have just studied.

In the factory, on the farm, or in your daily tasks, time is important. Of course, you could take a day or a month, if you wanted to move one ton of earth from one place to another. The amount of work you did would be the same, no matter how long you took to do it. But if you were paying for the job, you'd want it done in the shortest time possible. If you had other jobs to do as well, you'd want to get the work done as soon as you could.

So we want to know how fast a machine can work, as well as how much work it can do. How long will it take to do a certain amount of work? In other words, at what *rate* will it do work? We want to know the *power* of a machine, because *power means the rate of doing work.* Power means working against time, you might say.

More power helps us to do a job in less time. You might walk two miles in about 30 minutes. By adding more power — your own muscle-power — you might run those two miles in perhaps 20 minutes. By adding the power of a horse, as people did years ago, you could get there still more quickly. Nowadays you can get even more power, by using an automobile, a bus, or a train. The added power helps you to do the job in less time.

When you use the power of a car, an airplane, or even a horse, though, notice that something special is happening. You are using power that is not your own muscle power. You see, man has not used machines just to multiply his own muscles, just to harness his own energy. He has seen the wild energy in nature — the energy in the wind, in running water, in fire, in chemicals hidden in the earth, in lightning. Man has harnessed these energies. Now he is struggling to put a harness on the energy that lights the sun itself. Because energy — and machines — mean power. Power to help do the world's work, and to help people to play, too. Power to make the world a better place to live in for everyone.

LOOKING BACK

Tool Words

To be sure you understand the key words below, write the statements in your notebook and replace each blank with the correct word from the list. DO NOT MARK THIS BOOK.

stored energy	force	wheel and axle
energy of motion	work	efficiency
heat energy	friction	inclined plane
chemical energy	inertia	block and tackle
radiant energy	lever	screw
transformation of energy	mechanical advantage	wedge
machine		

1. Anything that moves has . . .
2. Any device that helps man do work is called a . . . .
3. When a force moves an object, . . . is done.
4. Six simple machines are . . . , . . . , . . . , . . . , . . . , ...
5. Two things that resist your force are . . . and . . . .
6. The amount of useful work done divided by the amount of work put into a machine shows its . . . .
7. A woodsman uses a . . . , as well as an ax, for splitting logs.
8. Striking a match is an example of . . . .
9. A brake wheel on top of a freight car is an example of . . . .
10. The . . . of an inclined plane, neglecting friction, is found by dividing its length by its height.

GOING FURTHER

In the Laboratory and Field

1. *Making a teeterboard — a lever.* Make a teeterboard by placing the middle of a plank about 12 feet long over a sawhorse. Let one person get on the plank 1 foot from the sawhorse. Push down with enough force 6 feet away from the opposite end of the sawhorse to raise the first end of the plank from the ground.

ROBERT YARNALL RICHIE

This crane (made up of simple machines) easily lifts and swings this heavy block of granite out of a quarry. What simple machines do you see in this photograph? *Project:* For the next week carry a small notebook and list all examples of simple machines you see.

Now do the same, but with the person at the far end of the plank. In which position did you use less force? Where on a lever should a fulcrum be to move a large weight with little force?

2. *Experimenting with the lever.* With heavy string suspend a yardstick so that it balances. Next, hang a small pail on a spring scale. Put enough weight into the pail to make it weigh about 5 pounds — nails will do, for instance.

Now hang the handle of the pail over the end of the yardstick and four inches from the supporting string. Put the hook of the spring scale over the other side of the yardstick, four inches from the string. Pull downward until the pail is lifted about two inches. Read the scale as you pull.

Now move the spring scale over to the

farther end of the yardstick. Again pull downward until the pail is lifted about two inches. Read the scale. How does this show that this lever helps you to do work?

3. From a wooden frame hang small pulleys and a small block and tackle supplied from your school laboratory, as in Fig. 239C. With a five-pound pail as weight, and your spring scale to measure the force used, record the following data for *each type of pulley:*

a. The reading of the spring scale compared with the weight of the pail.

b. The distance the weight moves compared with the distance the force moves. How does this simple machine help you to do work?

Put on Your Thinking Cap

1. What simple machine are you using when you use:
   - *a.* a can opener
   - *b.* an auto jack
   - *c.* a vise
   - *d.* a key
   - *e.* scissors
   - *f.* an oar
   - *g.* Venetian blinds
   - *h.* a toothbrush
   - *i.* a screw driver
   - *j.* a ramp

2. Which of these *needs* friction to work?
   - *a.* a nail filer
   - *b.* an eraser
   - *c.* a pencil
   - *d.* automobile tires
   - *e.* a pulley
   - *f.* a knife

3. If you could mount a large wheel so that it could turn *without friction* of any kind, and you gave it a push to start it turning, it would:
   - *a.* gradually turn faster and faster
   - *b.* turn forever at the same speed
   - *c.* gradually slow down and stop
   - *d.* quickly slow down and stop

   Explain your answer!

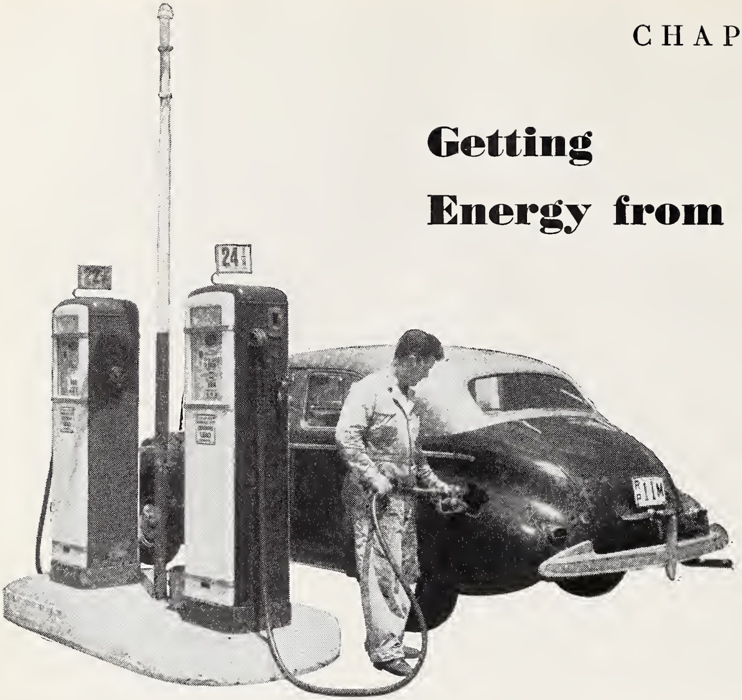
Adding to Your Library

1. *The Wonderful World of Energy* by Lancelot Hogben, Garden City (Doubleday), 1957. The illustrations are superb; for example, the one showing how a 100-ton stone column was erected with simple machines and muscles only. You will find more information on just how the lever and the wheel and axle work, too. Chances are you will find yourself exploring the whole book.

2. *Everyday Machines and How They Work* by Herman Schneider, Whittlesey, 1950. Locks and keys, scissors, pencil sharpeners, and a host of other machines we use every day — you will look at them in a new way after you have seen them taken apart in this intriguing book.

CHAPTER 23

Getting Energy from Fuels



Simple machines multiply your muscle. But the machines we call engines add to your energy the energy of fuels. So today you have more energy than the richest man could command 100 years ago.

If you could have been in Alexandria, Egypt, on a hot summer's day almost 2,000 years ago, you might have seen one of the first attempts that we know about to use the energy of steam.

The First Steam Engine

A young man named Hero had often boiled water in a pottery jar. Noticing that the force of the steam as it escaped kept lifting up the cover, he thought that, if the steam could push up a cover, it might be made to move other things. So Hero made an engine like the one in Fig. 240.

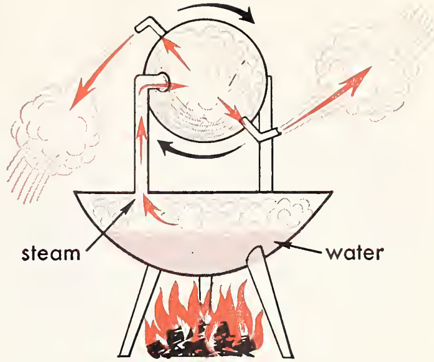
Hero placed two bent metal tubes on opposite sides of a hollow ball. He then mounted the hollow ball so that it would turn easily. Then he filled the boiler half full of water and built a wood fire under it. The steam rushing out of the ends of the bent tubes set the ball turning in the same way water rushing out of the bent tubes of a lawn sprinkler sets a sprinkler turning. This motion is caused by

the force of the jet of steam or water. As the steam or water pushes away from the tubes, the tubes are pushed away from the steam or water (p. 456).

You can show how the energy of steam can be made to move an object. With a nail and hammer punch holes diagonally across from each other near two corners of a small pepper can. These holes should be about one-half inch above the bottom and just around the corner on the broad surface of the can. Put about two tablespoonfuls of water in the can and close the opening in the top. Hang the tin to the ring of a ring stand by the handle of thread attached with pieces of adhesive tape to each side of the can (Fig. 241). The can should balance and swing freely. Now heat the bottom of the can with a Bunsen burner or alcohol lamp. What comes out of the holes? What makes the can whirl?

Hero's engine, of course, had very little power, probably only enough to turn itself. But to the people of Alexandria, and to you if you could have been there, it was a marvelous thing; for it turned by itself without using the muscles of men or of horses and without being blown by the wind or pushed by running water. It used the energy in *fuel*.

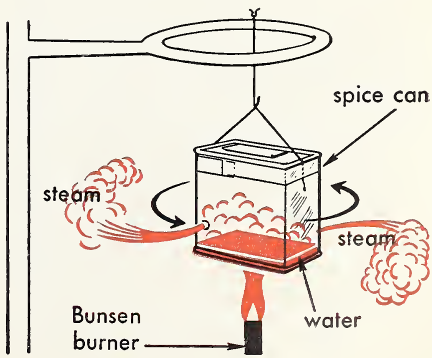
Hero's fuel was wood, and wood was the main fuel for almost 2,000 years after Hero. Today we have many different kinds of fuels, and complex engines to make use of them. Many of these fuels you know; for example, you use gasoline in a car or power lawn mower. You use oil or coal in your furnace to change stored energy in fuel into heat energy for heating your home. Still other kinds of fuels are being developed to give the powerful thrust needed to send a rocket beyond the earth.



240 Hero's steam engine. Why does the ball turn?

In this chapter you will see how fuels produce energy, and how we use this energy, in place of muscle power, to operate machines. You will see some of the effects these machines have had on civilization. You will begin to understand what an important effect *power* has — and will have — on your life. As you will see, the search for new fuels, and new engines to use them, goes on.

241 What causes the spice can to whirl when the water inside is changed to steam?



FUELS

Have you ever had to strike a match two or three times before it burst into flame? The reason the match didn't light the first time reveals something important about fuels, oddly enough. It has to do with *kindling temperature*. There is a lowest temperature at which any fuel will start to burn. A fuel won't burn until it reaches this temperature. This temperature is called the *kindling temperature* of the fuel.

To Light a Fire

Fuels have different kindling temperatures. For example, rubbing the head of a paper match on a rough surface heats chemical fuel in the match head. This small amount of heat makes these chemicals burn. So when you have to strike a match several times, it means that you haven't raised the temperature of the match head to the kindling temperature. You haven't generated enough heat by friction.

The heat of the burning match head is enough to cause the paper of the match to burn. The paper has a higher kindling temperature than the chemicals in the match head. Wood matches are made to burn the same way. Wood kindling can be set on fire by the heat of burning paper. Coal has a higher kindling temperature than wood but can be set on fire by the heat of burning kindling wood. Coal fires are usually started with kindling wood because the heat from a tiny burning match is not enough to set fire to a piece of coal of ordinary size. However, a match or even a spark may set fire to powdered coal or dust.

Certain fuels, such as natural gas, alcohol, gasoline, and some cleaning fluids, have very low kindling temperatures. They can be set on fire easily by the heat of a burning match or even a spark.

How Do Fuels Burn?

Some fuels, like coke or charcoal, are almost pure carbon. But most fuels contain hydrogen as well as carbon, as do gasoline and kerosene, for example. What happens to the hydrogen and carbon when these fuels burn? When the kindling temperature is reached, and if there is enough oxygen on hand, the carbon burns completely to make carbon dioxide. The hydrogen burns completely to make steam. As chemists write it,

hydrogen + oxygen → steam + heat
carbon + oxygen →
carbon dioxide + heat.[1]

When these fuels burn, a great deal of energy is given off in the form of heat. But fuels differ in the amount of heat energy they give off. The more heat energy given off for each pound of fuel, the more useful the fuel may be, of course. Notice how the heat energy in fuels differs, as shown in Fig. 242. A pound of gasoline has four times the heat energy of a pound of dry wood. Coal has three times as much heat energy per pound as wood. Note that the amount of each fuel is the same.

Fuels differ in another important way, in speed with which they burn.

[1] In chemical symbols

$$2H_2 + O_2 \rightarrow 2H_2O + \text{heat}$$
$$C + O_2 \rightarrow CO_2 + \text{heat}$$

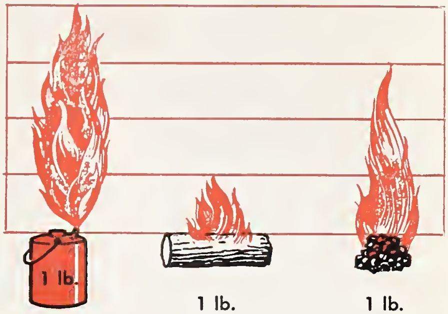
Solid fuels like coal and wood can burn slowly, giving off heat energy for a long time. On the other hand, gaseous fuels, like natural gas, can burn very quickly. In fact, when they are mixed with the right amount of air, gaseous fuels can burn so quickly that they *explode*. An explosion is merely very rapid burning of a fuel. Gasoline, for instance, forms gases easily. These gases are exploded, that is, burned very rapidly, in the gasoline engine. The burning is started by an electric spark. Gasoline, when mixed with the right amount of air, has more explosive force than dynamite, pound for pound.

The ease with which the gases explode is the reason why it is dangerous to use gasoline indoors, or to light a match in a room where a fuel gas may have been escaping. Some cleaning fluids, too, are as explosive as gasoline. Even flour or coal dust, when mixed with air, can burn so quickly and release its heat energy so speedily that the result is an explosion.

Do Fuels Burn Completely?

You may have wondered why we put in the word "completely" when we said, three paragraphs back, "carbon burns completely to make carbon dioxide," and "hydrogen burns completely to make steam." There was a reason for that.

Fuels don't always burn completely. Gasoline, for instance, is never completely burned in an automobile engine. Gasoline, you remember, contains carbon and hydrogen. When the carbon in the gasoline burns incompletely it forms carbon monoxide, a poisonous gas, and

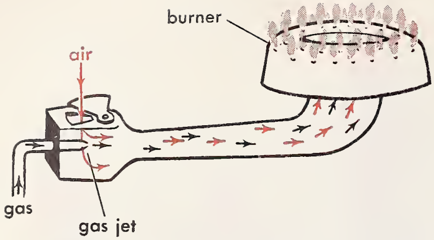


242 Do you think that each of these fuels gives off the same total amount of heat energy?

solid carbon, a hard black substance which coats the inside of the engine. When much carbon forms, the engine no longer runs smoothly. Perhaps you have heard someone say, "I think the car needs a carbon job." He means that it is time to have the solid carbon resulting from incomplete burning cleaned out of the engine.

Carbon monoxide gas is formed in the automobile engine because of incomplete burning; that is, only half the oxygen needed for complete burning combines with carbon. This carbon monoxide gas is a deadly poison. Every now and then newspapers tell of someone found dead in his car in the garage, with the motor running and the garage doors closed. The odorless carbon monoxide gas, produced in the motor, fills the garage. When it is breathed into the body, it goes into the blood stream by way of the lungs. The red cells in the blood take up carbon monoxide very easily so that soon the blood is so full of carbon monoxide that it cannot carry enough oxygen to keep the body cells alive.

Gas used for cooking and heating



243 The right mixture of gas and air is needed for complete burning of the fuel.

may contain or may form carbon monoxide. This is one reason why you should make sure that every gas burner in your home is safely turned off when not in use.

It is very important that a fuel be properly mixed with the right amount of air and burned. Have you ever looked at a gas range burner to see how this is done? In the pipe that leads to the burner is an opening (Fig. 243). As the gas passes by this opening in the pipe, air enters and is mixed with the gas. When this air-gas mixture is lit, there is the right amount of oxygen in it to burn the hydrogen and carbon of the gas. When the hydrogen and carbon burn completely, all the heat energy of the fuel is given off.

It makes a difference what method is used to burn a fuel, if you want all the heat energy. In a coal furnace, for example, much of the heat of the fuel may go up the chimney. Modern furnaces are built so that the heat passes back and forth in the furnace, under water jackets or tubes, before going up the chimney. In this way most of the heat energy is used. Blowers are sometimes used to force air through burning coal, to get more complete burning and more heat. Such newer ways of getting more heat energy from the same amount of coal have given us cheaper electric power, for instance.

Fuel oil, when it is properly burned, gives off more heat per pound than coal. But the engineer has to design a stove or furnace that will not lose a lot of the heat energy up the chimney. Natural gas has now become available as a fuel in many places far from natural gas wells, thanks to long-distance high-pressure pipe lines. But it too has to be burned as completely as possible to get the full benefit of the heat energy stored in it. Even though furnaces and stoves have been with us for quite a while (Fig. 244), engineers and inventors are still working to make better ones.

Today we have many different fuels and many ways of burning them. We also have many kinds of machines which make use of these fuels. The search for more fuels and more engines to use them has not ended; in fact it is going on harder then ever. We have come a long way from Hero's little steam engine of almost 2,000 years ago.

STEAM ENGINES

Hero's engine demonstrated an idea, the idea of using steam for power. But it didn't do any useful work. Who made the first steam engine that did some useful work? It is difficult to find out, and we are not sure. But a man named Thomas Savery was certainly among the first to make a useful steam engine. He did so about 1,700 years after Hero made his engine. As you will see, once there was a real need for more power and the idea of getting it from steam took hold, other improvements developed from Savery's machine.

The "Miner's Friend"

Thomas Savery called his engine the "Miner's Friend." It pumped water. Indeed, it couldn't do anything else. But anything that pumped water was certainly the miner's friend, because coal miners were digging deeper and water was flooding into the mines faster. If miners were to work, the water had to be pumped out. The old horse-powered and hand-powered pumps couldn't keep up with the job. More power was needed badly.

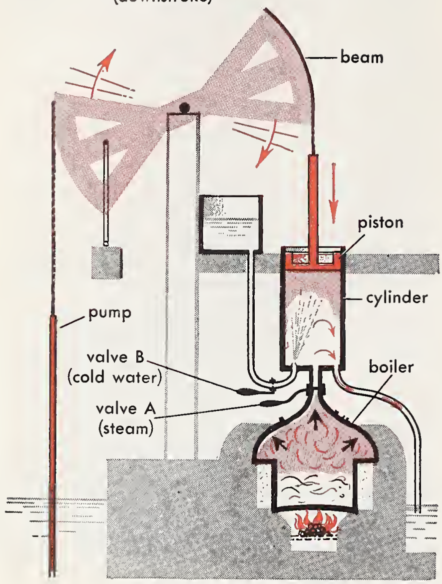
You can demonstrate with a drinking straw and a glass of water the idea behind Savery's engine and show how it worked. First, put the straw in the water and *suck* some water into your mouth. Second, point the straw upwards and *blow* the water out. This is just what Savery's engine did: it sucked water from below, in the mine, and blew it out up above.

Savery's engine had a metal tank, shaped rather like a lemon. From the lower end a pipe went down into the water. It had a valve that could be opened or closed. First, Savery let hot steam into the tank, by opening a valve in the steam pipe. This forced the air out of the tank. Then he turned another valve and squirted a little cold water onto the tank full of steam. The cold water cooled the tank and made the steam *condense;* that is, change from steam to water. The result was that a good *vacuum* formed in the tank. So when Savery opened the valve in the pipe that went down to the water, water rushed into the tank and filled the vacuum. Savery knew, as you do, that the pressure of the atmosphere was what pushed the water up the pipe into the tank to fill the vacuum. Of course, when you suck on a straw you make a vacuum in your mouth, and atmospheric pressure forces your drink up the straw into the vacuum in just the same way. This is also the same principle on which a medicine dropper works.

PHOTO FROM L. L. BEAN, INC.

244 Benjamin Franklin invented this type of stove to give more heat than the open fireplaces widely used in his day.

Thus Savery used steam to get water up into the tank. The next step was even simpler. He closed the valve in the pipe going down to the water, and opened the valve in a pipe going up from the top of the tank. Then he let steam into the tank again, but this time the pressure of the steam entering the tank forced the water out the pipe in the top of the tank and up to a still higher level, out of the mine.



245 One of the first useful steam engines. Can you figure out the principle on which it operates?

In this way the "Miner's Friend" pumped water. But as you can imagine, Savery's engine didn't work very fast. All the valves had to be opened and closed by hand. And if the steam pressure got too high, the tank or the boiler where the steam was made was likely to burst. Boilers were not strong in those days.

Just the same, Thomas Savery had made a useful steam engine. When an English iron worker named Thomas Newcomen saw it, the idea came to him that he could build a better engine than that.

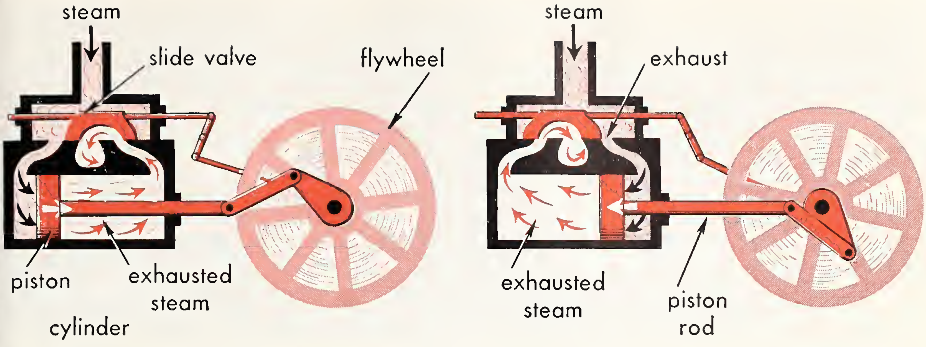
Newcomen's Engine

Strangely enough, Newcomen used the same facts and principles that Savery had used in his engine: that steam can be condensed to make a vacuum, that atmospheric pressure can be used to fill the vacuum and do work, and that steam pressure can do work too. But he used these facts in a different way.

Newcomen knew that steam takes up 1,700 times as much space as the water from which it comes. So he thought of letting steam escape into a cylinder where it would *push a piston upward* (Fig. 245). Then the steam would be condensed by a squirt of cold water, from valve B. This would make a vacuum in the piston, and the pressure of the air would *force the piston down* into the vacuum. Then another valve, A, would be opened so that steam could enter the cylinder again, pushing the piston up, and the whole process would be repeated. By connecting the piston to a beam, the Newcomen engine was able to pump water out of coal mines (Fig. 245).

The curious thing about this engine is that the pressure of the atmosphere, not steam, does the useful work of pumping! The steam pressure is used just to push the piston back up again. The pressure of the atmosphere forcing the piston down into the vacuum does the real work of pumping. But this way of doing it had a great advantage. It meant that there was no need for high-pressure steam. Considering how unreliable boilers were then, this feature of Newcomen's engine probably saved quite a few lives.

Of course, this engine worked very slowly, too, making perhaps 5 or 6 strokes in a minute. Here's how one eyewitness described it. The working of a Newcomen engine, he says, "was a clumsy and apparently a very painful process, accompanied by an



WATT'S STEAM ENGINE

246 In Watt's steam engine, the motion of the slide valve changes the direction of the steam entering the cylinder (*left*). The slide valve moves to the right, allowing steam to rush into the cylinder in front of the piston, forcing the piston to the right. This moves the flywheel (*right*). The slide valve moves to the left, allowing steam to rush into the cylinder in back of the piston, forcing the piston to the left. This keeps the flywheel turning.

extraordinary amount of wheezing, sighing, creaking and bumping. When the pump descended there was heard a plunge, a heavy sigh, and a loud bump; then, as it rose, and the sucker began to act, there was heard a creak, a wheeze, another bump, and then a rush of water as it was lifted and poured out."[1]

As you can guess, the Newcomen engine was very inefficient. It wasted much of its heat energy, and took vast amounts of coal. It was just as well that it was usually near a coal mine.

The Newcomen engine was a huge, lumbering monster of an engine. But it did its work well enough. In fact, for more than 50 years it had no rival. Then, just as Thomas Newcomen had seen Savery's engine and started wondering, a Scotsman named James Watt saw a Newcomen engine — and started wondering.

[1] From Samuel Smiles's *Life of Stephenson*, quoted in *Art and the Industrial Revolution* by Francis D. Klingender, Noel Carrington, London, 1947.

James Watt and the Age of Steam

James Watt made many improvements in the Newcomen engine. Indeed, he and the men who worked with him changed it almost completely from a slow, heavy, very inefficient machine for pumping water into a faster, lighter, more efficient and much more powerful engine that could do many jobs. Figure 246 shows how Watt's engine worked. Notice that steam pressure, not atmospheric pressure, does the work. And the steam pushes the piston first on one side, then on the other side, so that there is power when the piston slides forward as well as when it slides backward. When the steam has done its work inside the cylinder, it is allowed to escape into the air. The old wasteful way of condensing the steam with cold water is gone. These are only a few of the improvements Watt (and his co-workers) made, and these improvements ushered in a new era of machines.

Steam Starts an Industrial Revolution

James Watt died in 1814, but not before he had seen his steam engine start the Industrial Revolution, the greatest revolution the world had known. In the eighteenth century, England's most important industry was the spinning and weaving of cloth by hand. New machines for spinning and weaving were invented, but they needed more power than was at hand. More and more coal was needed to give this power. Fortunately, the power from Watt's engine helped to mine more coal by lifting it to the surface from deep down in the mines, and by pumping water out of the mines. The coal was then burned to make steam to run the steam engines of mills. People who had done their weaving on small hand looms moved to cities to find work, where miles of cotton and wool cloth were being woven daily in great factories powered by steam engines. As this change from work by hand to work by machine spread, more and more people moved to cities where they would be near the factories in which they worked.

One of Watt's assistants, William Murdock, dreamed of putting the steam engine into a carriage to make it go without a horse. In fact, he made a small experimental model which ran very well, but Watt thought that there was no future in that sort of invention and Murdock gave it up. Had he built a full-sized one, the rough roads of those days would have wrecked it anyway.

George Stephenson, an English engineer, got the idea of putting a steam engine on rails. In 1814 he succeeded in hauling ten coal cars at the dizzy speed of four miles an hour! Thus a locomotive was born, and from it came the network of railroads in our modern system of transportation.

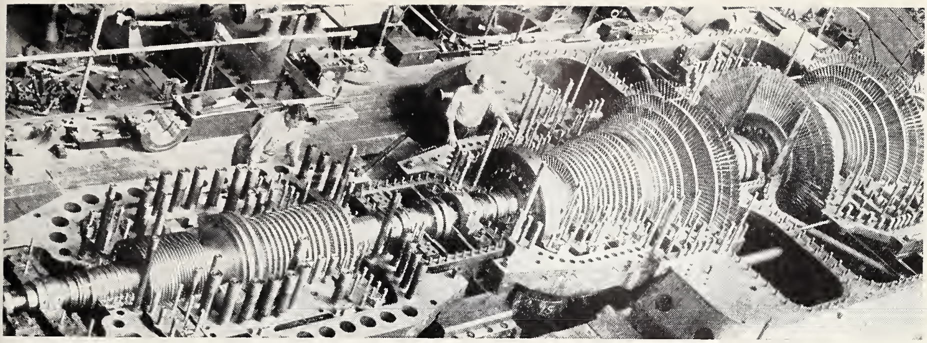
Imagine yourself among a crowd that gathered on the banks of the Hudson River in 1807. You would have been amazed and perhaps somewhat fearful to see a ship without sails belching forth flame and smoke. Yet it was moving up the river against tide and wind. Although other ships had used the power of steam to move against both wind and tide, the *Clermont*, Robert Fulton's ship, was one of the first to make a successful trip. He had taken care not to repeat the mistakes of other inventors.

Parsons' Turbine

Watt's steam engine, and others like it, wasted a great deal of the energy of steam. Not much of the heat energy in the steam was used up before it left the engine.

Over 60 years ago Charles Parsons, another English engineer, thought of another way to get more work from steam. He made a machine that looked like a series of fan blades of different sizes, one behind the other. The blades were carefully designed to use up the energy of the steam as it passed from one row of blades to the next. As it did so, it turned the wheel on which the blades were fixed.

When this bladed wheel was placed in an outer shell, the steam entered the shell at high pressure and temperature. When the waste steam came out, it had given up most of its heat energy. Meanwhile, this energy had been used to make the shaft of the wheel turn at high speed. Parsons



WESTINGHOUSE

247 This is one of our most powerful modern steam turbines (with the upper half of its outer shell removed). Why are the rows of blades placed carefully in a circle, one behind the other?

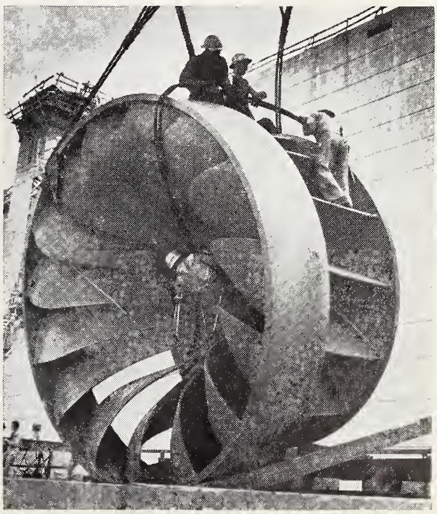
found that his machine, called a *turbine* (TER-bin), would run at a speed of 1,800 revolutions per minute as long as high-pressure steam entered it. Moreover, for its size and light weight, it gave an amazing amount of power. Many steam turbines today give over 50 times the power of Parsons' turbine (Fig. 247). Steam turbines do much of the world's work in giving power to industry.

Other turbines, built somewhat like the steam turbine, make use of the energy of falling water. The Francis wheel, a water turbine, has blades placed in its rim (Fig. 248). It is used where water falls with great force. To make the water in rivers fall with enough force to turn water turbines, dams are built to raise the water level. That is why at the base of most large dams you will find plants where huge dynamos, machines which produce electricity, are turned by the energy of motion of falling water.

Water turbines are now built that have adjustable blades. The angle at which the blades are set can be changed while the turbine is in use. These adjustable blades not only make for higher efficiency but mean that the turbine can be used as a *pump*, too! Below some dams where water is used to make extra electric power it is very convenient to be able to pump water back up behind the dam, so that it may be used again for extra power, whenever the need for it arises.

248 A Francis wheel turbine for the TVA Cherokee Dam. Note the huge blades that cause the turbine to whirl by making use of the energy of falling water.

TENNESSEE VALLEY AUTHORITY



Just now another kind of turbine is coming into wide use. It is called the *gas turbine*. If you have ever had a ride in a "prop-jet" or "turbo-jet" airplane, you have made use of the gas turbine engine. But because it is really a member of another family of engines, the *internal combustion* engines, we had better take a look at its parents first.

GASOLINE AND DIESEL ENGINES

Perhaps the handiest example of what "internal combustion" means is — you. For you *burn* the fuel you take in, food, *inside* your body. This is all that "internal combustion" means: burning fuel inside.

The steam engine and turbine burn their fuel *outside* the engine. Coal or oil makes heat under a boiler; the boiler makes steam; and the steam has to be piped into the engine. You have only to stand near a boiler to discover one difficulty with this system. It leaks heat, in the most wasteful way. So the idea came to some men, watching the steam engine at work, of whether it would not be much more efficient to have the fuel burn *inside* the engine. Why not burn the fuel right inside the cylinder of the engine, where the heat is wanted? Thus the idea of *internal combustion engines* was born.

But to turn the idea into a practical, useful engine took much work by many inventors and engineers. There was the problem of what fuel to use, for instance. What could you burn inside the cylinder that would expand and force the piston down? It turned out that the first successful practical internal combustion engines ran on "illuminating gas," as people called it then, the kind of gas you probably use in your gas range or gas furnace.

It is hard to say just who should get the credit for the invention of an engine that would make use of the energy caused by the explosion of gasoline. Certainly men had thought about it ever since the drilling of the first oil well in 1859. A German engineer named Nikolaus Otto (NIK-oh-lowss·AW-toh) is listed in the records as having built the first practical internal-combustion engine to run on liquid fuel in 1886.

You have learned that a liquid fuel such as gasoline forms a gas even at low temperatures. This gas, when mixed with the right amount of air, is a very explosive mixture. This means that the mixture of gasoline and air burns almost instantly, releasing a great amount of energy. The problem, of course, was to find a way to harness this energy to do the useful work of turning wheels or moving levers — in a word, to turn it into energy of motion. How the gasoline engine works hasn't changed much, in principle, since Nikolaus Otto heard the first bangs from his invention.

How Does a Gasoline Engine Work?

The modern gasoline engine is one of our best engines for giving power. In automobiles and trucks, these engines have four, six, and eight cylinders. In airplanes there are many more cylinders. However, each cylinder does the same kind of work. You need to know how one cylinder works before you can understand how

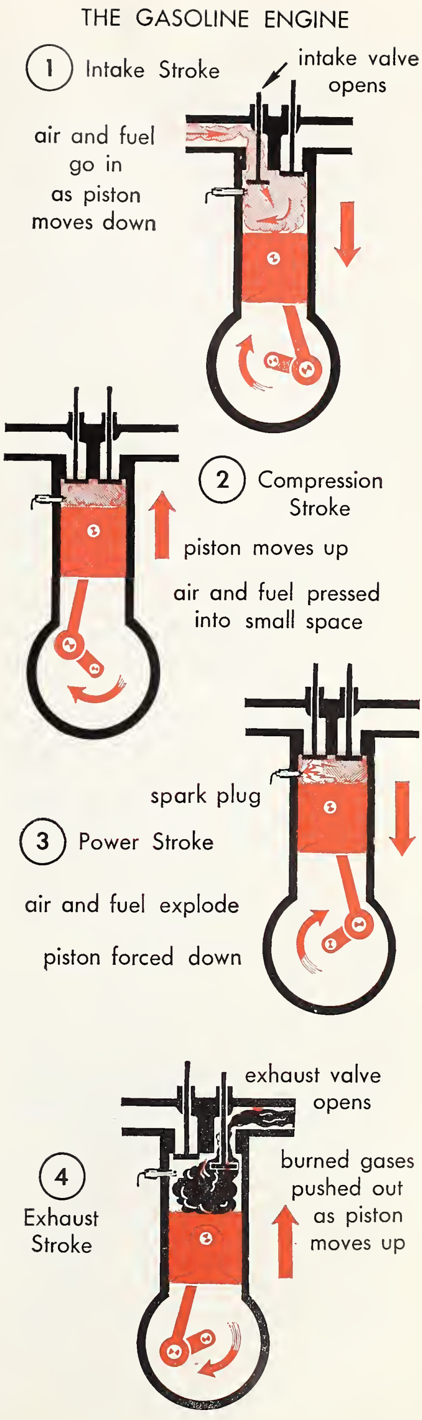
the many cylinders of large engines work.

There are thousands of one-cylinder gasoline engines used for sawing wood, for hand cultivating and plowing, and for cutting grass. All of them have these parts:

1. A *cylinder*.
2. A *piston* which is tightly fitted into the cylinder.
3. *Valves* to let in a mixture of gasoline and air and to let out waste or exhaust gases.
4. A *spark plug* whose spark explodes the mixture of gasoline and air.
5. A *timing device* to bring the spark to the cylinder at just the right time.
6. A *rod from the piston* which connects with the engine's crankshaft.
7. A *flywheel*.
8. *Oil* to make the moving parts move more smoothly.

The Strokes of a Gasoline Engine

The strokes of a gasoline engine give it power. But what are strokes? In the steam engine the piston moves to and fro in the cylinder. Each movement is a *stroke*, forced by the entering steam. In the gasoline engine, strokes are forced by the explosion of the fuel mixture of gasoline vapor and air. Here is the way it works. Study Fig. 249 carefully as you read.



249 The four strokes of a gasoline engine. What causes the power stroke?

1. *The intake stroke.* The piston moves downward in the cylinder, letting in a mixture of gasoline vapor and air, as the intake valve in the cylinder is opened. It is like your bicycle pump, in a way. When you pull the handle, air rushes into the pump through an open valve.

2. *The compression stroke.* When you push against the handle of your bicycle pump, you push air into your tire. You *compress* the air; that is, you press it into a small space. In the gasoline engine the piston moves *upward* against the mixture of gasoline and air. Both intake and exhaust valves are now closed. The piston is fitted so tightly into the cylinder that no gas can escape (Fig. 249). The movement of the piston pushes the mixture of gas and air into a small space. The gas is now compressed. This pressure against the fuel mixture makes it very hot.

3. *The power stroke.* An electric spark (Fig. 249) jumps across the spark plug when the piston reaches the end of the compression stroke. Immediately, the mixture of gasoline and air explodes. The hot gases resulting from the explosion expand and force the piston downward. *This gives the gasoline engine its power.*

A connecting rod from the piston to the shaft causes the shaft to turn (Fig. 249). A heavy wheel attached to the shaft turns also. The movement of this wheel, called the flywheel, brings the piston up into the cylinder again.

4. *The exhaust stroke.* As the piston moves upward, the exhaust valve opens. The rising piston pushes out the gases that remain after the power stroke. Every trace of the burned mixture, except some unburned carbon, is pushed out of the exhaust pipe. When the piston reaches the end of its exhaust stroke and starts downward again, the intake valve opens and another intake stroke begins. Thus the strokes of the gasoline engine come one after another. If the strokes do not come one after another, the engine may fail to work.

Look again at Fig. 249. See if you can describe the four strokes of the engine — the *intake*, *compression*, *power*, and *exhaust* strokes.

The Diesel Engine

The compression stroke of the gasoline engine squeezes the fuel-and-air mixture into a small space. This, as we have said, makes the mixture very hot. Rudolf Diesel, a German engineer, thought about this fact — and began to wonder if he could use it to make an engine *without spark plugs.* After many trials and experiments he succeeded, and the engine he invented is named after him.

Nearly four-fifths of all power used in the United States comes from internal-combustion engines in automobiles, trucks, trains, buses, ships, tractors, bulldozers, and small power plants. For heavy work the Diesel engine, rather than a gasoline engine, is often used.

The Diesel engine (Fig. 250) is very much like the four-stroke gasoline engine. It is different only in three ways. Compare Fig. 250 with Fig. 249 and note carefully the differences as you read.

1. The intake stroke admits air only — no fuel — through an intake valve.

2. The tight-fitting piston, moving upward in the cylinder, compresses this air in such a small space that the air is heated to a high temperature.

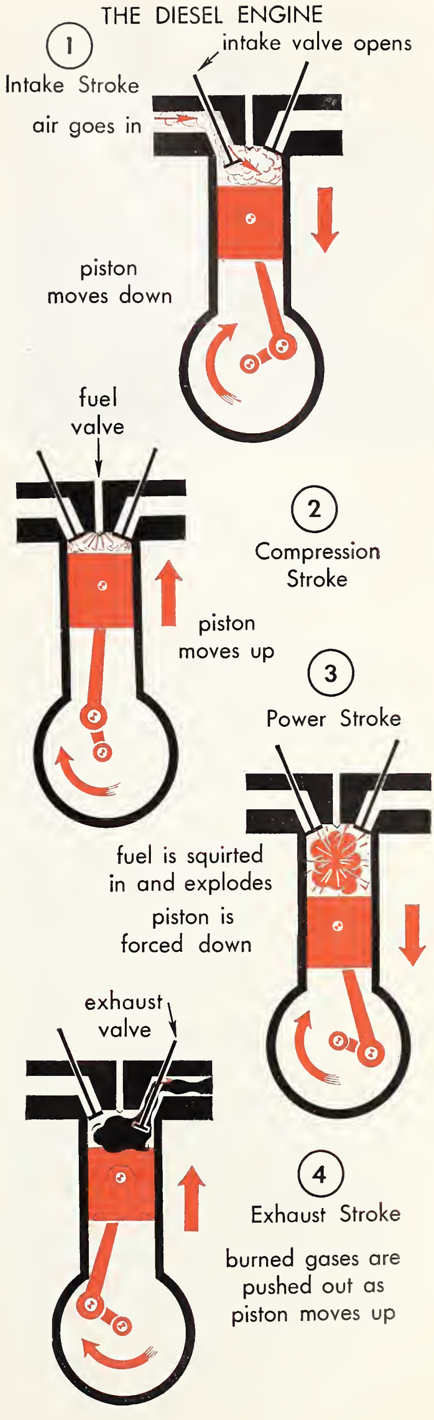
(This temperature is far above the kindling temperature of heavy fuels such as the oil used in Diesel engines.)

3. Just at this point fuel oil under heavy pressure is sprayed into the cylinder. The air has become so hot that the mixture of fuel oil and air explodes. (A Diesel engine has no spark plugs.) This explosion forces the piston downward with great force. On the next stroke the upward movement of the piston pushes out the burned gases through an exhaust valve. Then the cycles are repeated, as in the gasoline engine (Fig. 249).

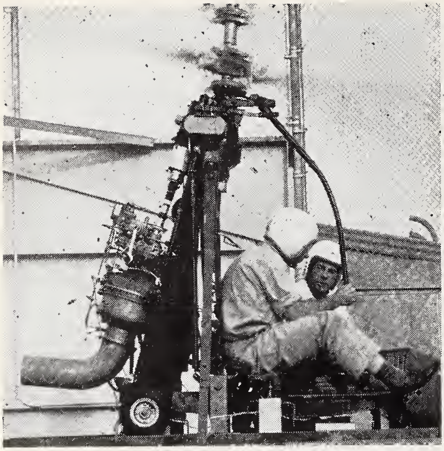
In moving heavy loads the Diesel engine is more useful than the gasoline engine because it can get more heat energy from a cheaper grade of fuel. Also, Diesel engines are heavier engines. Because of the strong compression stroke, they need the strength of a thick-walled cylinder. A gasoline engine of the same power is lighter — and better, therefore, in automobiles and airplanes. Diesel engines are very useful in locomotives hauling modern trains. Look about you if you live near a rail center and note the many Diesel locomotives.

The Gas Turbine

Now we come to an engine which is really so simple that you may wonder why it took so long to develop. But as you will see, there were good reasons for the delay.



250 The four strokes of a Diesel engine. What causes the power stroke?



SOLAR AIRCRAFT COMPANY

251 Ground test of a helicopter engine. The power for turning the blades is provided by a gas turbine connected to the blade shaft.

Here is what happens in the gas turbine engine as shown in Fig. 251. First, air is taken in. This air is crammed into a smaller space by the compressor fan blades. Next, a fuel mixture is squirted into this compressed air and lit. As it burns and gives off great heat, the compressed air starts to expand tremendously. The only way this expanding, exploding air and fuel mixture can escape is through the blades of the turbine. But the blades of the turbine are well designed so that any gas passing through must spin the turbine and deliver power to any machine connected to the turbine shaft, in this instance the helicopter blades. Thus the gas turbine is a kind of windmill set in the path of a furnace for making a tremendous wind!

Why did it take so long to invent, then? Notice that the wind that spins the turbine is no ordinary breeze, but a small volcano of flaming hot gases that come roaring out of the combustion chambers at a speed of more than 3,000 miles per hour. So the turbine, blades and all, has to be made of materials that can withstand terrific heat without weakening. Moreover, the turbine spins at very high speed. This, too, puts great strain on its parts, which have to be prevented from flying off in all directions like water from a spinning lawn sprinkler. Metals, combinations of metals, and turbine designs that could stand up to this sort of punishment have only recently been developed by scientists and engineers. Some turbine blades, for example, are hollow, and a stream of cooling air is pumped through each blade as it spins.

In exchange for all this trouble, gas turbines deliver a great deal of power — more than any piston engine can, in fact. The gas turbine engine gives more power for its weight than any other engine except the rocket engine. It can run for a long time without needing an overhaul. Since the turbine runs at high speed, the gas turbine engine must be "geared down" for slower-speed jobs, such as spinning the rotors of a helicopter, or turning the propellers of an airplane or a boat, or running an electric power generator. But it does deliver great power from a small engine. Since the turbine spins steadily in one direction (it doesn't plunge back and forth like the pistons in your car engine), it delivers smooth, almost vibrationless power. How useful this is in airplanes you will see in Chapter 25, "Modern Pack Horses." Some day you may ride in an automobile that gets its "horsepower" from a small but powerful gas turbine engine (Fig. 251).

HORSEPOWER AND YOU

The term "horsepower" was first used by James Watt when he was trying to sell his steam engine. He thought in this way: "My engine can do the work of several horses in a certain length of time. But how can I describe the power of my engine?" After careful measurement, he decided that a strong horse could do about 33,000 foot-pounds of work[1] in 1 minute. So if one of his engines could do work at the rate of 33,000 foot-pounds per minute, Watt described the engine as having 1 horsepower. If an engine could do 5 times as much work in a minute (5 × 33,000 foot-pounds), he called it a "5-horsepower" engine. We use just the same kind of way of measuring power today.

Your "Horsepower"

How do you compare with a horse when it comes to doing work? With your teacher's permission, you can find out what your horsepower is. To do so you will need to know your weight, and you will need a flight of stairs, a ruler or yardstick for measuring the height of the flight of stairs, and a stop-watch or a watch with a second hand.

To find what your horsepower is, run up the flight of stairs as fast as you can — and with the watch observe how many seconds it takes you to do it. Then measure the height of the stair flight. With these figures, and your weight, you can compute your horsepower. Here's how:

Suppose, for example, that your data turned out like this:

Weight: 100 pounds
Height of stairs: 20 feet
Time to run up stairs: 9 seconds

First, let's see how much work you did going up the stairs. Work is found by multiplying force by the distance the force moves, you remember. You lifted your weight upstairs, so the force is the same as your weight, 100 pounds. You lifted your weight a height of 20 feet, so the distance the force moved is 20 feet — the vertical height from the bottom to the top of the stairs.

Work = Force × Distance
Work = 100 pounds × 20 feet
Work = 2,000 foot-pounds

Notice that, whether you walk or run up the stairs, it makes no difference in the amount of *work* you do! But *power* is something else. Let's see now how much *power* you developed; in other words, how much work you did in a certain amount of time.

You did 2,000 foot-pounds of work in the 9 seconds it took you to gallop up the stairs. Two thousand foot-pounds divided by 9 seconds equals

222 foot-pounds of work in one second.

This is your *power*, the work you did in a certain length of time.

How does this power compare with a horsepower? As James Watt said, one horsepower is equal to 33,000 foot-pounds of work done in one minute. This is the same as 550 foot-pounds of work done in one second. Now, the 222 foot-pounds of work you did in one second is close to half of 550 foot-pounds of work in

[1] If you are not sure what "work" and "foot-pounds" mean, see Chapter 22, p. 440, again.

one second (which is 1 horsepower). So you have produced by your own energy close to one-half horsepower.

You can't produce that power for very long, can you! But engines can keep on producing horsepower — and far more of it than mere muscles can produce — to do the world's work and to help the world play.

Cost of Power

Today, one problem is to get power as cheaply as we can. The cost of the horsepower we can get depends upon many things. Here are a few things that must be considered:

1. The source of power (wood, coal, natural gas, gasoline, atomic energy, wind, and water).
2. The engine used (stationary steam, steam turbine, water turbine, gasoline, Diesel, or gas turbine).
3. The available energy per pound of fuel.

Only a very small amount of our nation's energy supplies have been tapped. This is particularly true of water power. Great dams have been built — Hoover, Grand Coulee, and those in the Tennessee Valley, to mention a few. They harness the energy of rivers and produce power by making electricity. More dams will store up flood waters and make the power of electrical energy of greater use to the life of our nation. It may be possible to use the energy of tides to produce power. Solar energy may be harnessed.

Even though we seem to have a wealth of energy supplies waiting to be tapped, we are beginning to see that we must not waste them; we must use our energy supplies carefully. The demand for more energy to do the world's work is growing tremendously, and the rate at which we are using up our resources is going up day by day. The number of people living on our globe is increasing too. All of us want the good things that power, machines, and supplies of energy can bring. We must make sure that there is energy enough to go around — and see that it does. This is one reason why our engineers and scientists are at work in "underdeveloped" lands, helping people there to build dams and electric power plants, for example.

Energy from Molecules

You strike a match. Its chemical energy is transformed into light and heat energy. In this transformation, the atoms in the chemicals — the oxygen in the air and the chemicals in the match — arrange themselves in a new combination to form new molecules. And in doing so they release energy — the light you see and the heat you feel as the fuel burns.

Until recently, shifting atoms around to make different molecules was how we got energy from fuels. Energy from molecules, in other words. We then changed this energy of burning fuels to other types of energy to do work — the energy of steam, of electricity, of expanding gases to provide mechanical energy.

Now, things are different. We can do more than shift atoms about to make new molecules and release energy. As you learned in Unit Five there is, in the nucleus of the atom, energy so great that it makes the energy we get from molecules look puny. Atomic energy is already being used to provide heat to turn generators of electric power which you use

in many ways and almost every minute of your life. Because of electric power alone you have more power than the richest man living a hundred years ago. Electricity, how it works and how it makes power, is the subject you will read about in the next chapter.

LOOKING BACK

Tool Words

These words are keys to important ideas in the chapter you have just read. Do you know what they mean? Test yourself by putting the right key word in the blanks below.

power stroke	heat energy
turbine	"Miner's Friend"
internal combustion	James Watt
horsepower	Charles Parsons
kindling temperature	Rudolf Diesel
exhaust stroke	gas turbine
carbon monoxide	

1. The temperature at which a substance catches fire and burns is called . . . .

2. The . . . is used where a steam engine of light weight and high speed is needed.

3. Gasoline, Diesel, and gas turbine engines are all . . . . . . engines.

4. The . . . stroke of the piston pushes waste gases out of the cylinder of a gasoline engine.

5. The . . . . . . happens when the fuel mixture explodes inside the cylinder.

6. Power is measured in terms of . . . .

7. A dangerous gas made when gasoline burns incompletely in the auto engine is . . . .

8. A new light, powerful and almost vibrationless engine is the . . . .

9. Because it pumped water, Thomas Savery's engine was called . . . .

10. We burn fuels to get . . . .

11. This man invented the steam turbine: . . . .

12. This man made an internal combustion engine that needed no spark plugs: . . . .

13. By making a lighter, more powerful, more efficient steam engine this man helped start a revolution: . . . .

Test Yourself

Copy the phrase in List A. Before the phrase write the letter of the word from List B that is most related to it. DO NOT MARK THIS BOOK.

List A	*List B*
1. the first jet engine	*a.* carbon monoxide
2. fuel starts to burn	*b.* Watt
3. 4 times as much heat energy as wood	*c.* internal combustion
4. a dangerous gas	*d.* power stroke
5. the first useful steam engine	*e.* Hero
6. atmospheric pressure engine	*f.* kindling temperature
7. steam pressure engine	*g.* 2 horsepower
8. steam turbine	*h.* Diesel
9. fuel burns inside the cylinder	*i.* Parsons
10. gasoline vapor explodes and does work	*j.* Savery
11. runs on fuel oil; no spark plugs	*k.* Newcomen
12. runs at high speed in great heat	*l.* carbon
13. 66,000 foot-pounds in one minute	*m.* gas turbine
14. a product of internal combustion of gasoline	*n.* gasoline

GOING FURTHER

1. *Kindling temperatures.* On separate asbestos mats, place a match, a piece of paper, a small block of wood, and a chip of soft coal. Light a Bunsen burner and direct its flame on each article until each one catches fire, that is, until you notice the articles giving off light and heat. Make a note of the time needed for each article to catch fire. List them in order of the time they take to reach their kindling temperatures.

2. *Force of steam.* Fill a test tube one-quarter full of water. Cover the outside of a cork stopper with Vaseline and insert it into the mouth of the test tube. Holding the test tube with a test-tube holder, with the corked end pointed away from you and everyone else, bring the bottom of the tube into the flame of a Bunsen burner. When the water starts to boil, what happens? What do you conclude as to the force of steam?

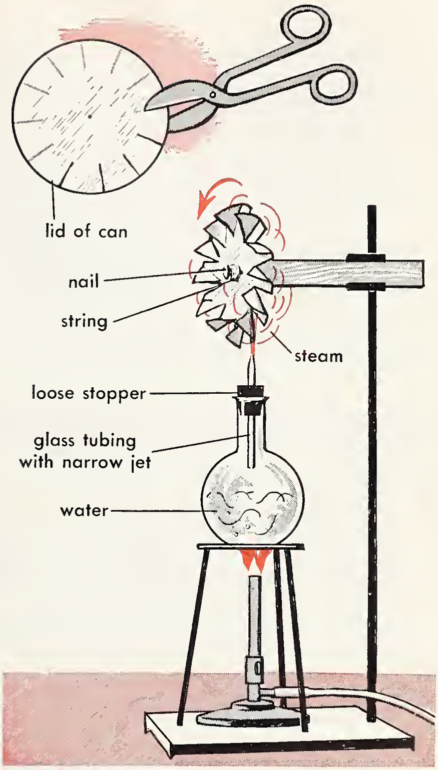
3. *Model turbine.* Insert into a one-hole stopper a glass tube that has been narrowed down at one end. Insert the stopper into the mouth of a flask one-quarter full of water. With a pair of tin cutters make a series of cuts about $1\frac{1}{2}$ inches long and 1 inch apart on the rim of the cover of a tin can that has no lip. With a pair of pliers, twist the notched pieces of tin so that they are somewhat like the blades in Fig. 252. Pierce the center of the cover with a nail. Wind a short length of string around the nail on each side of the cover so that the cover will turn on the nail easily and yet not move along the nail. Now attach the nail with its cover to a ring stand.

Heat the flask, which is now under the

cover. The force of the steam coming from the narrow end of the glass tube strikes the tin blades of the cover, and the cover turns on the nail. What does this show you about the force of steam? Do you think that this model turbine is very efficient? Why?

Put on Your Thinking Cap

1. Why does steam give power?
2. What would you use to light
a. a wood fire?
b. a coal fire?
c. gasoline vapor and air in a gasoline engine?
3. What happened when the steam engine was invented?
4. Which engine would you use — stationary, steam, steam turbine, water turbine, gasoline, Diesel — for the following work:
a. Making electricity at the foot of large dams.
b. Pumping water into the large water pipes of a city.
c. Running a power lawn mower.
d. Sawing wood with a power saw.
5. A man weighing 160 pounds and carrying a 5-pound bag of sugar ran up a flight of stairs to the floor above. The vertical distance was 10 feet, and his time was 6 seconds. Which of the following numbers tells the horsepower he used in running up the stairs: $3\frac{1}{2}$, 1, $\frac{3}{4}$, $\frac{1}{2}$?



252 Try making this model turbine.

Adding to Your Library

You will find interesting reading about power and machines in the following books:

1. *Machines That Built America* by Roger Burlingame, Harcourt, Brace, 1953. Read how the important machines that made a great nation were invented and built. You will especially like the chapter, "Six-Shooter."

2. *Everyday Machines and How They Work* by Herman Schneider and J. Bendick, McGraw, 1950. A wonderful collection of the machines you see and use every day, well explained.

3. *Faster and Faster: The Story of Speed* by Raymond F. Yates, Harper, 1956. The story of man's quest for speed, from muscles to jets.

4. *Engineers' Dreams* by Willy Ley, Viking, 1954. More about our efforts to get more energy for ourselves, one way and another. See, for instance, chapter 3, "The Tamed Volcano," which has to do with harnessing the earth's own heat energy; chapter 7, "Power from the Sun," that tantalizing prospect now nearer than ever; chapter 8, "Waves and Warm Water"; and chapter 9, "Harnessing the Winds," with modern windmill

designs. This book may give you some notion of what an engineer's work can be like, too, which may — who knows? — put ideas in your head.

5. *The Story of the Turbine*, General Electric Co. A pamphlet that explains the working of the steam turbine and its uses. Enough pamphlets for a class may be had by writing to the General Electric Co., Schenectady, N.Y.

6. *They Almost Made It* by Fred Reinfeld, Crowell, 1956. Tales of inventors of steam engines, steamboats, locomotives, etc.

7. *American Science and Invention* by Mitchell Wilson, Crown, 1958. Look up luckless John Fitch and fortunate Robert Fulton in this handsomely illustrated picture album of science.

8. *More Experiments in Science* by Nelson F. Beeler and Franklyn M. Branley, Crowell, 1950. Try "Energy Makes the World Go" and "Making a Turbine" in this collection of do-it-yourself experiments.

Careers for You

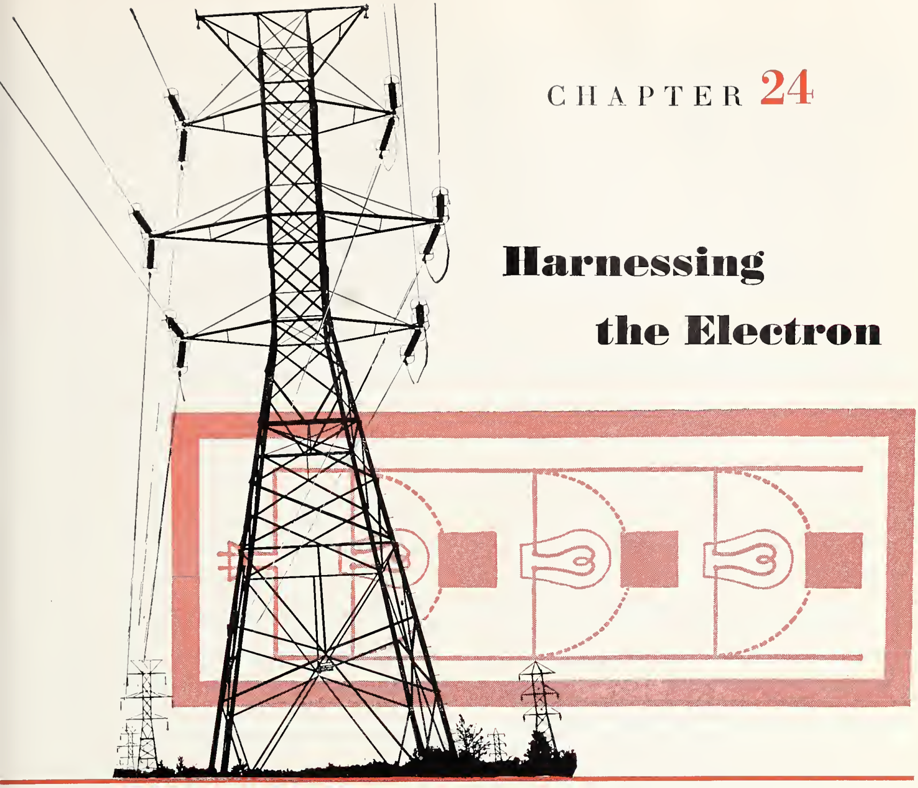
You can get an *engineering* education if you are interested. Many colleges have courses which a student takes for ten weeks, then works for an engineering company ten weeks. This goes on during the entire year, with no summer vacation. In five years the student gets his college degree and has had practical experience. Moreover, the student has earned most of his way through college.

Many large companies train their workers by sending them to college part-time while giving them paid part-time work. There are also scholarships if you are a good student and really interested in making engineering a career. To find what kind of engineering may be your choice, write to colleges for catalogues.

Have you ever thought of *teaching* as a career? The United States needs teachers badly, and, with an increase in population of 3 million people each year, the need will continue for a long time. We especially need teachers trained in science — teachers who can use the chapter you have just read as a springboard to give pupils further knowledge of power and machines that there is not room to discuss here; teachers who can work with students interested in science and start them on a scientific career in research, in industry, or in the nation's laboratories. Why not think of teaching?

CHAPTER 24

Harnessing the Electron



Press a button or flick a switch. A lamp lights, the radio goes on, a motor hums, a car starts. Electrons flow, that is, electricity flows. Man, the scientist, has harnessed the electron and put it to work for you.

WHY SHOULD a doctor be interested in hooking up frogs' legs, of all things, to an electric current? Let's visit the laboratory of Luigi Galvani (loo-EE-jee·gal-VAH-nee), an Italian doctor in the year 1790, to find the answer.

Galvani had stretched out a pair of frogs' legs on the bench in front of him. They were the legs of a very large and powerful frog, and they had looked so good to Galvani's wife that she had bought them for her husband's dinner.

That didn't matter to Galvani. He wasn't going to ruin the meat. He was just going to do another experiment to help him write a book about how animal flesh reacted to different kinds of metals.

Galvani took up a strip of iron and a strip of copper and touched the muscles of the frog's legs with the two metals. The legs started to twitch. He moved the metals over to another place. Again the legs twitched. Galvani took careful notes.

Galvani's notes went something like this: "The muscles and the nerves of a frog are affected (moved) by a strange force that is in the copper and iron strips. What that force is I do not know." Today a scientist would write this: "When two different metals are placed on the moist muscles of a frog, a tiny electric current is made that causes the muscles to twitch." The two notes are not so very different after all, are they? In modern terms the force is called "an electric current." That is just what Galvani's tiny force was.

In this chapter you will learn that electricity is the movement or flow of electrons from one place to another. You will understand how we make use of the power of electricity and why it is one of our greatest servants today.

STATIC ELECTRICITY

Amber is a hard, yellow substance. In ancient Greece people picked it up on the seashore and made it into ornaments. It remained for Thales (THAY-leez), a Greek philosopher who lived about 2,500 years ago, to find that amber, or "electra" as the Greeks called it, has a strange power. If rubbed quickly with a cloth, it attracts small particles, such as pieces of straw and dried leaves. However, Thales had no good explanation for this attraction, and this property of amber remained a mystery for centuries.

Electricity Gets Its Name

About 2,150 years after Thales, an English doctor named William Gilbert found that not only amber but also other materials such as wax, sulfur, mica, and glass have the power of attracting light articles when rubbed. Gilbert was the first to give this power a name. He called it *electricity*, from the Greek word "electra." But like Thales, he had no good explanation for the power.

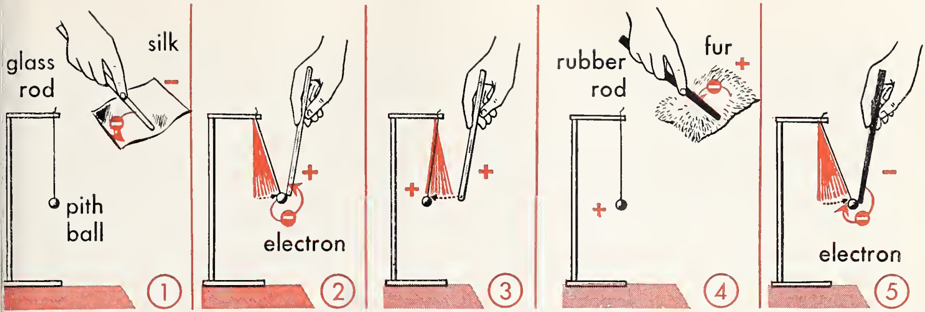
Today scientists know that Gilbert's "electricity" is *static* (STAT-ik) *electricity. Static* means "stationary." Therefore, static electricity is electricity that is "still" or "stationary." It is caused usually by friction, that is, the rubbing of one material over the surface of another. Once electricity flows, as in a wire, it is no longer static or stationary electricity but "current" or flowing electricity.

Positive and Negative

When an object has static electricity, it is said to be electrically charged. The electric charge on the object may be *positive* or *negative*. Let us see how this happens. In Chapter 14 you learned that atoms are made up of particles such as electrons, protons, and neutrons. The protons and neutrons are inside the nucleus; the electrons are outside. You also learned that electrons are always negatively charged. Protons are always positively charged.

In an atom the number of positive protons and negative electrons is the same. Therefore, the atom is electrically balanced. In other words, an atom has the *same* number of positive and negative charges. It is electrically *neutral*.

The electrons in some substances can be disturbed easily by friction or rubbing. They may be actually passed from one article to another. For example, when you rub a glass



253 Experiments with static electricity. When rubbed with a piece of silk, a glass rod loses electrons to the silk and becomes positively charged. Why is the pith ball attracted to the rod in 2 and repelled in 3? A rubber rod is given a negative charge by rubbing it with fur. Why is the pith ball attracted in 5? *Clues:* What happens to the electrons? Can protons move freely? Can electrons move freely?

rod with a silk cloth, some of the electrons (negative charges) from the rod pass to the cloth. This leaves the rod with fewer electrons. It has more positive charges than negative charges. The rod is thus said to be charged with positive electricity. The cloth has received electrons (negative charges) from the glass rod. The cloth is said, therefore, to be charged with negative electricity (*1* in Fig. 253).

On the other hand, if a hard rubber rod is rubbed with woolen cloth or a piece of fur, electrons from the cloth or fur pass to the rubber rod. In this instance the rubber rod, having received electrons, becomes negatively charged. The wool cloth or fur, having lost electrons, is positively charged.

Whenever an object loses electrons, it becomes unbalanced as far as its supply of electrons is concerned. It needs a supply of electrons to get back its balance. Therefore, the object draws (or attracts) electrons to itself. Thus the object which can attract electrons to itself is said to be positively charged. This is true of the glass rod. However, an object which has taken on more electrons than it needs is negatively charged. This is true of the rubber rod.

Would you like to see how two kinds of charges are produced and how they act?

Hang a pith ball from a ring stand by a silk thread. (A pith ball is about the size of the end of your little finger and is made from the inner part, or pith, of the dried stem of a plant.)

Now rub a glass rod briskly with a piece of silk. When you rub the glass rod with the silk cloth, the rod loses electrons to the cloth. Now touch the pith ball with the end of the rod (*2* and *3* in Fig. 253).

The rod, you remember, has lost electrons. It is now positively charged. That is, it can take on electrons to become electrically balanced. It takes some of these electrons from the pith ball. While the pith ball is giving up these electrons, it clings to the glass rod. After the pith ball has given up electrons it becomes positively charged and drops from the positive

glass rod. Now both rod and pith ball are positively charged. When the glass rod is brought near the pith ball again, the pith ball is pushed away or repelled. Now they both need electrons. But neither one has ready electrons to give to the other. What do you suppose will happen if you give the pith ball electrons in the following way?

Give a rubber rod a negative charge by rubbing it briskly with wool or a piece of fur. Bring the end of the rubber rod close to the positively charged pith ball. The pith ball, positively charged (it lost electrons to the glass rod), is attracted to the rubber rod, which has extra electrons. There it clings while taking electrons to get back its electrical balance. Its electrons now are equal in number to its protons. The pith ball is neutral again (*4* and *5* in Fig. 253).

From experiments like these, scientists have found that (1) friction between two different objects like glass and silk, or rubber and fur, places a positive charge on one and a negative charge on the other, (2) two objects with the same kind of charge (+ and + or − and −) repel each other, and (3) two objects with different charges (+ and −) attract each other. These findings may be stated in a simple law: *Like charges of electricity repel each other, and unlike charges of electricity attract each other.*

What Causes Electric Sparks?

The reason two objects with unlike charges of electricity attract each other is that one lacks electrons and the other has extra electrons. Thus two objects with unlike charges tend to draw together, and electrons may pass from the one with more electrons to the one with fewer electrons.

Ordinarily electrons do not pass through air easily. But whenever any charge of static electricity is great enough, a flow of electrons may pass from one object to another through the air. There is then an electric spark that may be felt as well as seen. Sometimes on a dry cold day you pick up electrons when you walk on a deep rug. When you touch a doorknob you may see and feel the spark jump across from your hand to the knob. Were you positively or negatively charged?

If you rub a cat's fur in the dark when the air is dry and cold, you will notice the sparks in the fur. Friction on the countless number of cat hairs builds up a great deal of static electricity. You see this static electricity pass between the hairs in the form of electric sparks.

Electric sparks, caused by static electricity, are feared by people who work in coal mines or in factories where flour or other powdery products are made. Fine dust is an explosive substance when mixed with air. Any source of static electricity is carefully watched so that a spark will not set off an explosion.

Drivers of gasoline trucks also fear static electricity. The friction of the sloshing gasoline inside the tank can build up a large charge of electricity. The rubber tires on the truck keep the electricity that is built up in the tank from passing into the earth. If there were no way to keep the charge of static electricity from building up, the gasoline might explode. But it does not. Why not? Next time you see a gasoline truck you may notice chains dragging on the ground as

the truck rolls along. The chains send the electrons built up in the tank into the earth in a steady flow.

Suppose there were no way to lead this charge into the earth. A spark jumping between the nozzle of the hose and the metal pipe leading to an underground tank might cause a bad explosion or fire.

Lightning

Lightning is a kind of great electric spark passing between charged clouds or between the clouds and the earth. How is this electric charge built up?

When air currents rise, they cause friction between the particles of water vapor in the clouds. This friction starts to build up an electrical charge. As the heat of this friction is built up, air currents and clouds move up and down more quickly. Of course, this makes the amount of friction greater, and larger charges of static electricity are built up in the clouds. Finally, a jagged flash, followed by thunder, breaks across the sky. The flash is a giant electric spark that is really a discharge of electrons from a negatively charged cloud to a positively charged cloud. Thunder is heard after the flash.

In the same way, there is a flash when heavily charged clouds move close to some point on the earth with an opposite charge. You see a bolt of lightning that passes between the clouds and the oppositely charged ground. The thunder is caused by the rush of the surrounding air to fill the space caused by the sudden expansion (pushing outward) of the air heated by lightning.

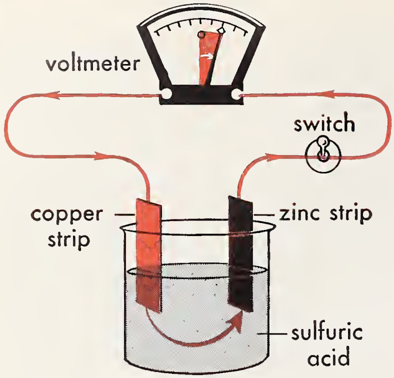
Lightning causes very little damage when we consider the great number of thunderstorms. Lightning rods on buildings and the steel in skyscrapers pass the flow of electrons harmlessly into the earth. Lightning should not be feared, provided you follow the simple rules mentioned in Chapter 12. Lightning is just a huge show of static electricity. This sudden great flow of electrons which causes lightning has been matched by man on a smaller scale. Every day in your home and school you start or stop a flow of electrons.

ELECTRONS AND THEIR FLOW

Have you ever thought how important a switch is on your bicycle headlight, your flashlight, or in your home? Switches are useful things. They start or stop a flow of electrons. But the electrons must have been produced somewhere. Where did they come from? Why does the flick of your finger on a switch heat an iron or light your home?

Volta's Cell

In 1796, Alessandro Volta, an Italian scientist, made a great discovery. He built an arrangement of zinc and copper disks like coins, separated by strips of leather soaked in salt. He connected the zinc and copper disks separately to wires. Whenever he touched the ends of the wires to the flesh of frogs' legs, he could make the legs jump. We now know that when he connected the zinc disks and the copper disks, electricity flowed through the wire connecting the disks. What Volta made is now called a voltaic pile in his honor. We would call a voltaic



254 The meter shows that an electric current (a flow of electrons) is produced by a simple voltaic cell. What is the source of the flow of electrons?

pile a battery. This was the first method used to make electricity flow through wires. This flow of electricity is called "current" electricity.

Later on Volta found that, if he put two different metals in a drinking glass holding acid and water, he could also get a current of electricity when the metals were connected by wires.

You can make this simple voltaic cell by placing a copper strip and a zinc strip in a solution of dilute sulfuric acid. Connect the zinc and the copper strips to a switch and a meter by using bell wire, as shown in Fig. 254. The meter measures the flow of the electrons. When you press the switch, the needle of the meter will move. This shows that a flow of electrons is coming from the voltaic cell. When you release the switch, the flow stops and the meter needle returns to its first position, that is, to 0.

The source of the flow of electrons in the voltaic cell is chemical action. The zinc and copper strips are called "poles," when used in a voltaic cell. When zinc and copper poles are placed in sulfuric acid, chemical action starts. The chemical action causes the copper strip, or positive pole, to give up electrons, and the zinc strip, or negative pole, to have a large supply of electrons. These electrons flow out through the wire. They go to the copper strip, or positive pole, which lacks electrons. In this way a complete path for the electrons is made. This path is called an *electric circuit.* When this happens we say we have a current or flow of electricity.

Flowing Electricity

What happens when you turn on a light in your room by pressing a switch? You join two ends of a wire inside the switch. Electrons flow along the wire from a source making electricity, through the light bulb in your room, and back to the source again. An electric circuit has been completed. When you turn off the light you open the switch, and no electrons can pass the gap. Wherever electricity is used, a complete electric circuit is made just by closing a switch. This action allows electrons to flow and do work in lighting, heating, and giving power to electric motors. Opening the switch breaks the electric circuit; closing the switch completes the circuit.

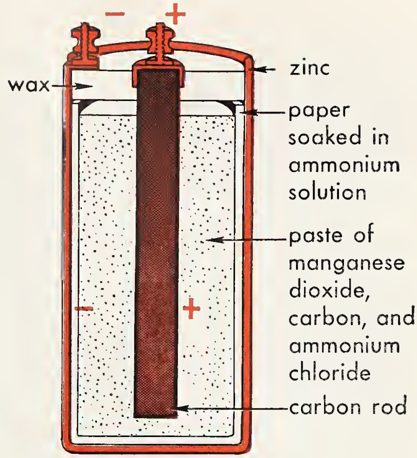
Have you ever had a choice of two guesses and made the wrong guess? Although Benjamin Franklin was one of our great scientists, he made a wrong guess about the direction in which electricity flows. He guessed that electricity passed from the positive pole to the negative pole. In this book we shall follow the modern evidence that electricity flows in the

opposite direction in a wire — from the negative pole to the positive (Fig. 254). And you know the reason: electric current is a flow of electrons. The flow has to start from the point where there is a great supply of electrons (negative charges), and that is at the negative pole.

The Dry Cell

The dry cell is today a common source of electricity. The dry cells in your flashlight are not really dry. Each cell is made up of the following materials: a zinc can that acts as the negative pole, and a carbon rod through the center that acts as the positive pole. Around the inside of the zinc can is a lining of paper that has been soaked in ammonium chloride. Between this paper and the carbon rod there is a paste of manganese dioxide, fine carbon particles, and ammonium chloride (Fig. 255). As in the voltaic cell, the source of the flow of electrons in the dry cell is chemical action. The zinc and carbon poles react with the ammonium chloride. This chemical action sends a flow of electrons from the negative zinc pole to the positive carbon pole when they are joined by a wire. However, hydrogen gas is made by the chemical action. It is removed by the manganese dioxide in the paste. If it were not removed, the hydrogen would act as a blanket to cover the carbon pole and the flow of electrons would lessen or stop.

When a dry cell is used for a long time, it grows weak because more hydrogen is made than can be taken care of by the manganese dioxide. Also, the ammonium chloride is being used up. After a rest the cell may get back some of its ability to give a



255 This is what you would see if you cut a dry cell lengthwise. *Project:* If you have some old, useless dry cells, take one apart. Can you find the parts shown above?

flow of electrons. This is so because the manganese dioxide has had time to remove extra hydrogen from around the carbon pole.

After further use, however, the dry cell goes "dead"; that is, chemical action has used up the ammonium chloride. Then no more electrons pass from the zinc pole to the carbon pole.

The Storage Battery

Storage batteries are used in automobiles and trucks for many things, such as electric lights and starters. These batteries yield a large amount of electric current by chemical action. In one type of storage battery sulfuric acid acts upon two different kinds of plates. One of these plates is made of a kind of spongy lead, and the other plate is made of lead peroxide. About 50 of these plates are placed in three separate cells of the battery, but all the plates are separated from each other by wood, rubber, plastic, or glass fiber sheets. All the spongy lead

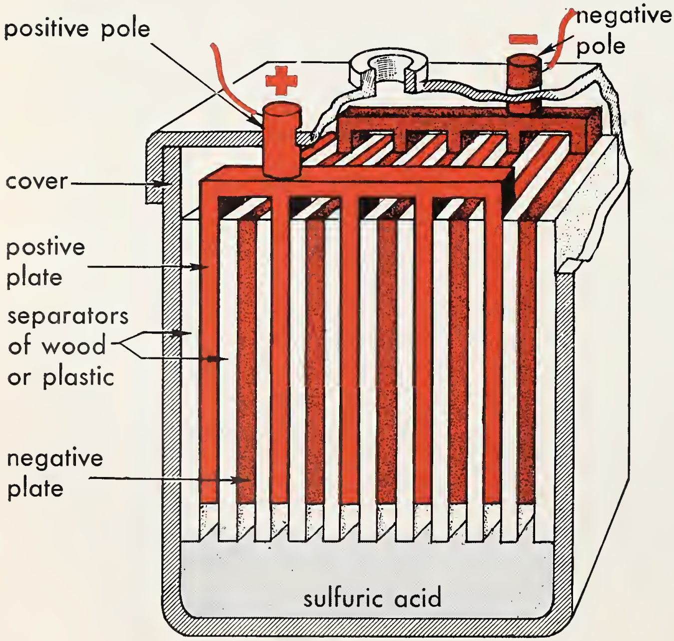
plates, the negative plates in each cell, are joined together. So are all the positive lead peroxide plates. When a complete circuit is made, there is a large current or flow of electrons from this battery (Fig. 256).

After a while chemical action in the storage battery changes both the spongy lead plates and the lead peroxide plates to a different kind of plate. This new kind of plate is made up of lead sulfate. The current then stops flowing. Why? You have learned that in voltaic cells and the dry cell the plates or poles are of different materials. Otherwise, there would be no flow of electrons. The storage battery must also have different kinds of plates. When a large part of all the plates has been changed to lead sulfate, the battery is "dead."

To keep the storage battery from going dead, we must recharge it by sending electrons into it from some other source. These new electrons flow into the battery in a direction opposite to that of the current coming from the battery. This current that we now send into the battery makes the plates unlike again. This is the sort of thing that happens in an automobile battery. While you are using electricity from your battery to run your engine and lighting system, your engine at the same time runs a device called a *generator*, which makes electrons flow back into your battery to keep it "charged." But if you keep lights on without running your engine, all the plates in your battery will become alike. Then your battery will be discharged and useless.

MAGNETISM AND ELECTRICITY

The shepherd Magnes (MAHG-nez), who lived long ago near the city of Magnesia in Asia Minor, made a



256 The inside of a storage battery, like the one used in an automobile to start the engine and light the headlights. How is this battery recharged?

surprising discovery. As the story goes, Magnes, while tending his flocks, found that the iron nails in his sandals as well as the iron tip on his staff were drawn to the earth. Digging down into the ground, he discovered a rock which stuck to his sandals. This was the natural magnet that is called loadstone. Because of its strange power, for thousands of years people believed that loadstone would cure many diseases and even toothaches.

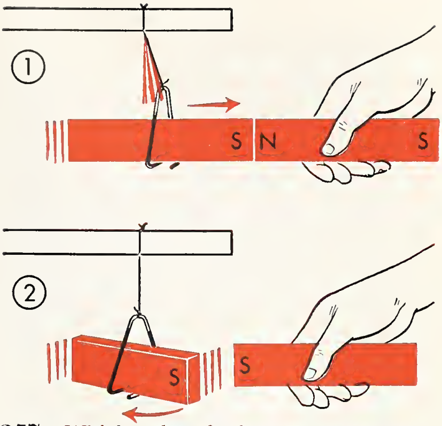
The First Magnet

Loadstone (or magnetic oxide of iron) is found in many countries of the world. It is this rock that was used in magnetizing needles for the first compasses. Today we have magnets made of steel or special alloys. These magnets are hundreds of times more powerful than loadstone. With electricity we can make even more powerful magnets.

How Magnets Act

Place a penny, a nail, a brass screw, a piece of glass, a gold ring, a piece of paper, and a paper clip on a table. Bring a bar magnet close to each one. (A bar magnet is a straight piece of magnetized metal, not U-shaped.) Which articles are attracted? Now bend a paper clip to form a hook at one end and a loop or cradle at the other. Lay a bar magnet upon the cradle, and hang the hook end from a support with a piece of string. Let the bar magnet come to rest. Does it point north and south?

You have now made a kind of compass. Why does a compass tell direction? It tells direction because the end of the magnetized bar or needle always points north and south.



257 Which poles of a bar magnet attract each other? Which poles repel?

Bring one end of another bar magnet near one end of the magnet in the cradle. Do the two attract or repel each other? Now bring the same end of the bar magnet near the other end of the magnet in the cradle that points north. What happens? By these experiments you have shown that magnets have certain properties.

Properties of Magnets

1. Magnets attract only certain substances, such as iron or steel.

2. When allowed to swing freely, one end of a horizontal straight magnet will point north and the other end will point south. In other words, a magnet has a north-seeking pole at one end and a south-seeking pole at the other end.

3. Unlike poles of magnets attract each other; like poles repel each other.

Making a Magnet

By using a magnet, you can make another magnet. Take a steel darning needle and stroke it from the middle to one end with the north pole of a bar magnet. Then cut a piece of a paper drinking straw the same length as the needle. Slit the straw in half from end to end with a sharp knife. Mark one end of one of the halves S, and the other end N. Place the needle in the straw with the end you stroked on the S end of the straw. The halved straw is now like a tiny boat, carrying the needle. Place the straw boat in a saucer of water. Bring the south pole of the bar magnet near the stroked end of the needle. The needle is repelled, and the boat swings around. This shows that you have made a south pole at this end of the needle by stroking it with the north pole of a magnet. Has a north pole been made in the other end of the needle at the same time? How would you find out?

Now let the darning needle on the floating straw come to rest and watch which way it points. Have you made a compass as well as a magnet?

This experiment has shown that:

1. A magnet can make another magnet.

2. The new magnet also has north and south poles.

3. The new magnet can act as a compass.

What Is Magnetism?

No one knows exactly what magnetism is or exactly how it makes magnets of metals. Since the invention of the first compass, men have known that the earth had a strange force that caused a compass needle to point north and south. We know now that the earth itself is a large magnet that causes this.

The north and south magnetic poles of the earth are some distance from the north and south geographic poles. A compass needle, therefore, points to these magnetic poles and not to the geographic poles. Maps are drawn showing the geographic poles. Fliers and ship captains, therefore, must be able to use the compass so that they can tell where they are at any time.

It is also known that some magnetized metals have stronger magnetism than others. The magnetism is also held for different lengths of time. Soft iron magnetizes easily and loses its magnetism just as easily. Steel magnetizes less easily but makes a strong magnet that holds its strength for a long time. An alloy called alnico, made of nickel and cobalt, magnetizes with difficulty. However, it makes a very strong magnet that holds its strength longer than any other metal.

Picturing Magnetism

Even though we don't know exactly what magnetism is, we can make a picture of it.

Place a glass plate or cardboard square over the length of a bar magnet. Shake some iron filings over the surface of the plate. Tap the plate gently with your finger. The iron filings take on a certain pattern (Fig. 258). Now take away the plate. Move the north pole of another bar magnet about one inch away from the south pole of the first. Place another glass plate over both poles,

sprinkle more iron filings over the plate, and tap as before. Examine the pattern (Fig. 258). Repeat, but this time with a glass plate over two like poles. Again look closely at the pattern.

You have found by these experiments the following facts:

1. Magnetism shows itself in a pattern called *lines of force.* These lines (shown by the pattern of iron filings) seem to go out in all directions — all around and through a magnet from the south to the north pole. The strength of a magnet depends upon the width or "field" of these lines of force.

2. Two unlike poles are attracted when the lines of force surrounding both poles are united.

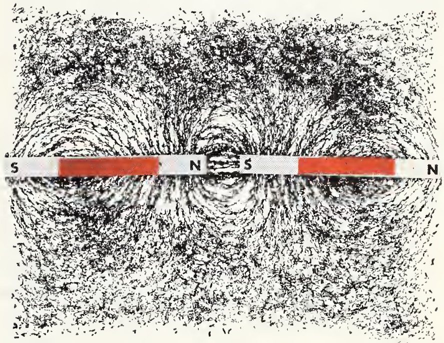
3. Two like poles are repelled when the lines of force surrounding both poles are repelled.

Magnetism from Electricity

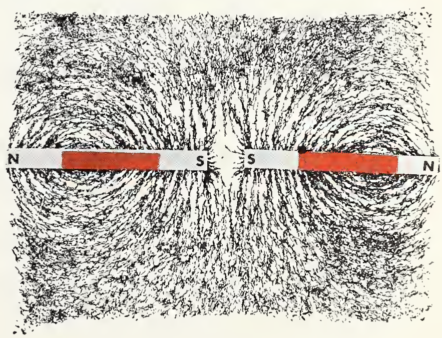
In 1819, Hans Oersted (UR-sted), a Danish scientist, made an exciting discovery. He found that when he held a wire carrying an electric current over a compass, the compass needle would turn away from its north-seeking position. He learned that any wire carrying a current of electricity has a magnetic field around it.

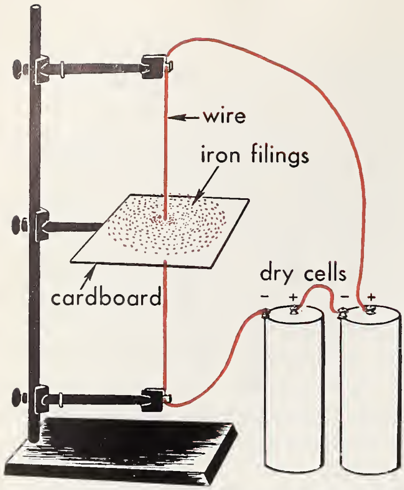
A year later, in 1820, a French scientist, André Ampère (an-DRAY·ahm-PAIR), found that a coil of wire carrying an electric current acted the same way as a magnet. That is, it had north and south poles. Later discoveries showed that a bar of soft iron placed in the center of the coil of wire would greatly add to the strength of this magnet. Today, industry uses huge electric magnets to lift and carry tons of steel from one place to another (Fig. 261).

You can easily do both Oersted's and Ampère's experiments. Punch a hole through the center of a cardboard square and pass a long length of heavy wire through the hole. Clamp about two feet of the wire to a ring stand (Fig. 259). The cardboard square is in the center of the wire. Attach the ends of the wire to the two terminals of a dry cell. Lightly sprinkle some iron filings on the cardboard around the wire and



258 Lines of force around and through a bar magnet. *Above,* attraction of unlike poles. Notice how the lines of force join. *Below,* repulsion of like poles. Notice how the lines of force push away from each other.





259 How did Oersted show that an electric current flowing through a wire produced magnetism?

tap the cardboard gently. What position do the iron filings take? How does this experiment help you to understand Oersted's discovery?

Now remove the wire from the battery and take away the cardboard square. Wind about two feet of the wire around a pencil to make a coil. Remove the pencil. Again attach the ends of the wire to the terminals of the dry cell. Bring one end of the coil near the north pole of a compass. Is there attraction or repulsion? Do the same with the other end of the coil (*1* in Fig. 260). You will find that a coil of wire carrying an electric current acts as a magnet with north and south poles.

Making an Electromagnet

The coil of wire that you have just made is really a weak *electromagnet* when it carries an electric current. But how are strong electromagnets made, that is, those that are able to lift and move tons of steel or iron? You can find out by doing a few simple experiments.

On a cardboard square sprinkle enough iron filings or tiny nails to make a small pile. Take the coil of wire you have just made and attach the ends of the wire to the two terminals of the dry cell. Now touch the pile of iron filings with one end of the coil. You will find that some of the filings are attracted by the coil.

Pass a steel knitting needle through the center of the coil and touch the filings as before. Now the steel knitting needle picks up some of the filings. The needle with its wire is an electromagnet, a magnet whose attraction for certain metals is due to electricity.

Use an iron spike in place of the knitting needle. The thick iron spike picks up more of the filings than did the needle.

Attach another dry cell to the first by joining the center terminal (+) of one to the side terminal (−) of the other with a short piece of wire. Attach the ends of the coil around the spike to the two other terminals of the cells and touch the filings as before. The iron spike picks up more iron filings because a stronger electric current flows through the coil.

Now wind six feet of wire around the spike. Attach the ends to the dry cells and repeat as before. You will find that the spike picks up more filings when more coils of wire carrying an electric current are wound around it (2 in Fig. 260).

By now you have come to some understanding about how strong electromagnets are made.

1. A strong magnet needs a heavy iron core (the iron spike).

2. A stronger electric current makes a stronger magnet.

3. More turns of a wire about the core make a stronger magnet.

A magnet that lifts tons of iron or steel must be made with a huge iron core with thousands of turns of wire carrying a powerful electric current.

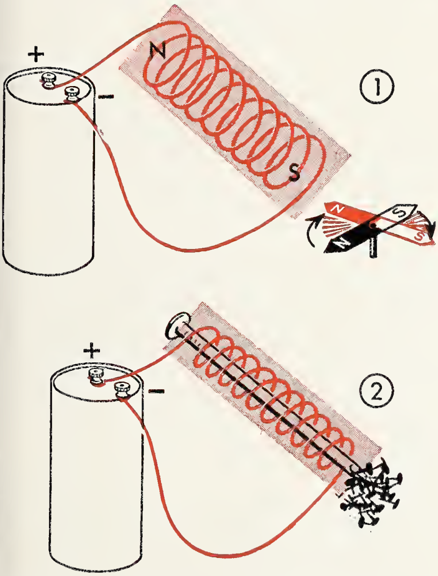
Electricity from Magnetism

About a hundred years ago the son of a blacksmith, who had not even a part of the knowledge you have today, became interested in science. At thirteen this boy went to work for a bookbinder. Luckily this job gave him a chance to read scientific books. He then was appointed a laboratory assistant and was allowed to work with the most famous scientists of England. Because of him, we know how to make electricity by using magnetism. He was Michael Faraday.

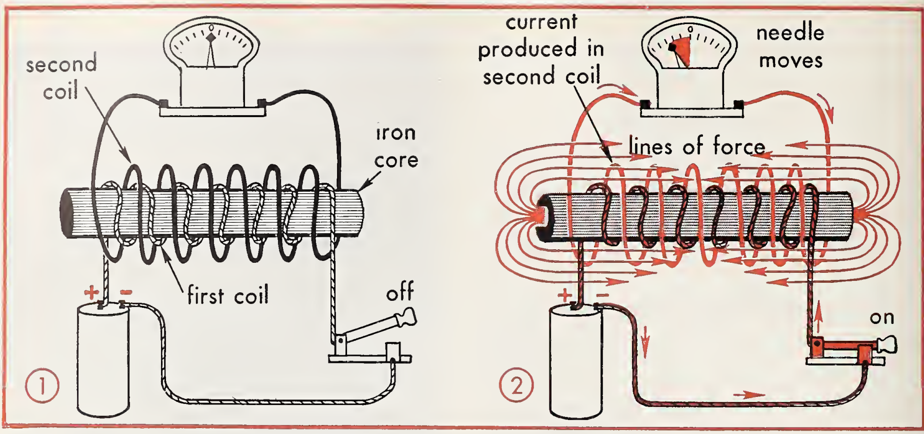
Faraday knew that Hans Oersted had discovered that electricity makes magnetism. Wasn't it possible to make electricity by using magnetism? Faraday did experiment after experiment to find the answer to this question. His first clue came when he wound two coils of wire alongside each other on an iron ring. He connected one of the coils to a meter that measured tiny electric currents. He connected the other coil to a battery (Fig. 262). Nothing happened, even though he connected over fifty batteries to the coil. How-

UNITED STATES STEEL CORP.

261 A huge electromagnet is used to lift and carry scrap steel (in this case discarded tricycles, sewing machines, shovels, and so on) from stockpiles to furnaces for melting.



260 An electric current flowing through a coil of wire (*1*) makes north and south poles. Why is the north pole of the compass attracted to one end of the coil? An iron core (here, a spike) thrust through the coil (*2*) makes it a magnet strong enough to pick up small tacks. *Project:* Can you make an electromagnet and show how it works?



262 Here is Faraday's discovery. When the switch is closed, lines of force from the first coil cut through the second coil. This causes a flow of electrons (electric current) in the second coil. Why does the needle of the meter swing back to zero (after being moved by the electric current)? Use the dynamo (*left*) to help you do the experiment on p. 489.

ever, he noticed one thing. Remember that one coil is connected to the meter only, and the other to the battery only. When Faraday completed the connection of the battery-coil circuit, the needle of the meter gave a jump. When he broke the connection of the battery-coil circuit, the needle gave another jump. Here was the answer. The battery circuit had caused a current in the second coil (connected to the meter) when the electric circuit was made and also when it was broken (Fig. 262). But how could this have happened?

The explanation is this:

1. The passage of an electric current through a coil of wire makes the coil a magnet.

2. This coil magnet sends out lines of force. We can say a magnetic field is formed the instant the switch is closed and a complete circuit is made (Fig. 262).

3. These lines of force "cut" through the second coil.

4. In cutting through the second coil, the lines of force cause a flow of electrons (an electric current) in the second coil.

In his later experiments Faraday made other discoveries. Almost at the same time an American scientist, Joseph Henry, working separately, made much the same discoveries.

Faraday found that, when a copper wire or coil is moved in a certain direction in a magnetic field, a current of electricity is made to flow in the wire. This happens when the magnetic lines of force are cut. If the copper wire is moved in the opposite direction, it cuts lines of force in the opposite direction as well, and the electricity in the wire flows in the opposite direction. This discovery was the first step toward making electricity the powerful servant it is today.

You can show how an electric current is made to flow in a wire when it is moved so that it cuts lines of force.

Attach a coil of wire to a sensitive meter (Fig. 262). Thrust a bar magnet quickly through the coil. Does the needle of the meter move? In what direction? Now pull the bar magnet quickly from the coil. In what direction does the needle move now? How does this experiment explain Faraday's discovery?

In an Electric Power Station

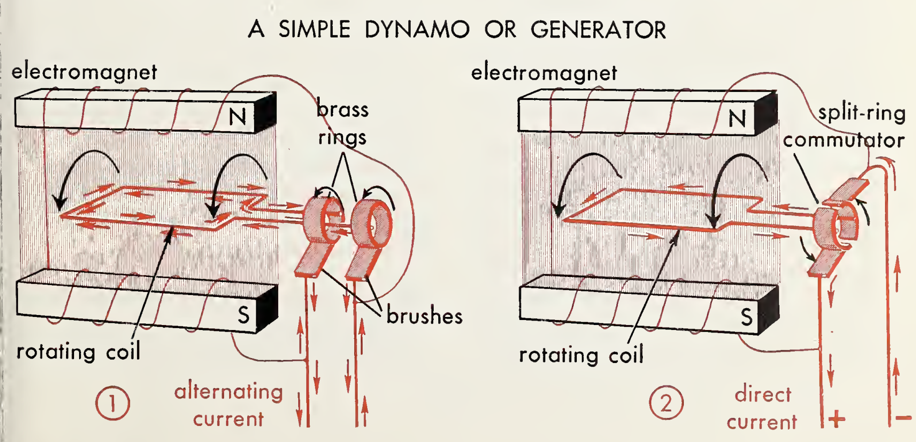
If you have ever visited an electric power station, you know that the energy of falling water or steam (from coal) is used for turning turbines. These turbines whirl coils of thousands of turns of copper wire through strong magnetic fields (made by magnets). These coils are the moving parts of huge *generators* or *dynamos* (DY-nuh-mohz).

What is a dynamo? It has, first of all, an *armature* (AHR-muh-cher). This is a moving part which, in the simple dynamo we are describing (Fig. 263) is made of only one coil of wire. Second, there is a magnet, between whose poles the armature turns. This magnet has a strong magnetic field. As the armature is turned in the magnetic field, its movement cuts across the magnetic lines of force and makes an electric current flow in the wire. To understand how electric generators or dynamos work, study the diagram along with the text. In Fig. 263 you will notice:

1. The electromagnet has north and south poles and a strong magnetic field.

2. As the coil of wire, the armature, makes one complete turn in this magnetic field, an electric current flows. In one complete turn, the loop of wire changes the direction in which it cuts the lines of force. Thus, the current flows first in one direction, then in the other direction, or, as we

263 In these simple dynamos, a coil of wire (armature) turns in a magnetic field. In *1*, the flow of electricity alternates in direction. It is called alternating current, or AC. In *2*, the current of electricity on the first half-turn of the armature flows out through one-half of the split ring. On the second half-turn, the armature cuts lines of force in the opposite direction, but the other half of the split ring sends the current in the same direction as the first flow. The current is called direct current, or DC. Do you have AC or DC in your home?



say, it *alternates* in its flow. Because the current moves in alternating directions, it is called an alternating current, or AC.

3. The ends of the armature are attached to two brass rings (*1* in Fig. 263). Steel brushes (made of replaceable, springy steel wire) rub on these brass rings. As they do this, they lead the alternating electric current off to an outside wire.

4. An alternating current can be changed to *direct current*, or DC, by using a device made like a split ring. You can see in *2* in Fig. 263 that the split ring is simply a ring which is split into two parts. (In measuring direct current, the needle of the meter [Fig. 262] remains steady. This shows that the current flows only in one direction. That is, it is a direct and not an alternating current. You will find that some electric devices will work only on AC or DC but not on both.)

Here is how electricity is made by dynamos at an electric power station: Falling water or steam turns turbines, which turn the armatures of huge generators. These armatures, thousands of coils of wire with iron cores, cut across magnetic fields of force. This makes a current of electricity, which is led off into wires.

The strength of the current produced depends upon how many magnetic lines of force the armature cuts each second. The strength of the current in turn depends on how strong the magnet is, how fast the armature turns, and the number of coils of wire in the armature. But remember that the armature cannot be turned without power. Hence dams are important. They furnish the energy of falling water to turn the huge armatures in the power stations. This does not mean, however, that all generators are huge. Millions of small generators are used in automobiles, trucks, buses, airplanes, and trains to make the electricity that helps them run. The generator in your automobile makes the electricity that charges the storage battery.

MAKING USE OF ELECTRICITY

In making any use of electricity you will want to know how much of it you need, how long you will need it, and how well it will do the job. You will want to know how to measure its flow, the force of pressure of its flow, and how much you use.

Measuring Electricity

Electricity flowing through a wire is somewhat like the flow of water through a hose. You know that there is a pressure behind the flow of water in the hose, because it leaves the nozzle with great force. You also know that a certain amount of water leaves the nozzle of the hose.

The pressure (like the pressure forcing water through a hose) forcing a flow of electricity through a wire is measured in units called *volts*. The electricity coming into your house probably has a pressure of 110 volts.[1]

How much electricity flows through a wire is measured in units called *amperes* (AM-peerz). An ampere is a measure of the flow of current (number of electrons), not its pressure.[2]

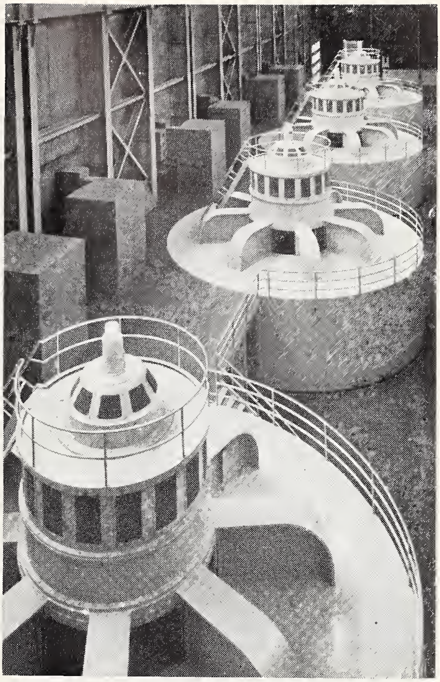
[1] Meters that measure this electrical pressure are called *voltmeters*.

[2] Instruments to measure the flow of electric current are called *ammeters*.

In other words, the volt is the unit for measuring the *pressure* of electricity. The ampere is the unit for measuring the *amount* of electrons passing through a wire. As you may have guessed, *volts* and *amperes* are named after the scientists Volta and Ampère.

Most electrical devices have marked on them the number of volts and amperes that they take. The number of volts and amperes shows you the pressure and flow of electricity needed to work any electric device.

You can often see another marked unit called a *watt*, named after James Watt. A watt is the unit that measures electricity in terms of power.[1] Power, as you remember, means the rate of doing work. For example, about 600 watts of electric power are used in heating your electric iron. Sixty watts may be the amount of electric power used in lighting an electric light bulb in your home. It may take 1,500 watts of electric power to heat a burner in your electric stove. The watts you use indicate the rate at which you use electricity. How does this electric power get to your home to be used?



BUREAU OF RECLAMATION

264 These four huge generators, running "full load," make electricity at the power plant of the Hungry Horse Project in Montana.

From Power Station to You

Anyone who visits the power stations at Niagara Falls, the Grand Coulee, or any TVA (Tennessee Valley Authority) dam can hear the powerful hum of giant generators (Fig. 263). Electricity is being made. Where does it go? That would seem easy to answer, wouldn't it? Just take some large copper wires, insulate them well with heavy rubber, and send the current into them. Then put up poles and lead these wires over the country into homes. Unfortunately, the problem isn't so simple as that.

For instance, certain generators at Niagara Falls give electricity a pressure of 2,200 volts. Your home electrical appliances, however, use only 110 volts, $\frac{1}{20}$ of that pressure. If 2,200 volts went into your house wires, it would be a real danger to life and property. It is clear that the high voltage must be brought down to the useful 110 volts. As scientists say, the high voltage must be transformed to a low voltage by means of a device called a *transformer*.

[1] 746 watts = 1 horsepower (p. 469).

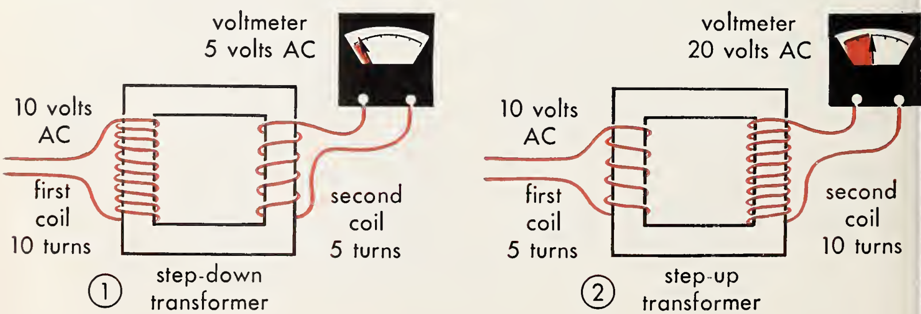
Transformers

Suppose we make a transformer. We may take a steel ring and wind two coils of wire around it. The first coil, connected to a source of alternating electric current, may have 40 turns of wire. In the second coil, entirely separated from the first, we have 20 turns. This second coil we have connected to a voltmeter. This instrument can tell us the voltage, or electric pressure. If we send 10 volts into the first coil (of 40 turns) and measure by the voltmeter the voltage produced in the second coil, we find the voltmeter reads not 10 volts, but 5. If we send 20 volts into the first coil, we find the voltage 10 volts in the second coil. Thus the voltage in the second coil is one-half the voltage sent into the first coil. Clearly, it is the difference in the number of turns of wire in the first and second coils which causes the difference in the voltage. The ratio of 40 turns of wire to 20 turns of wire is 2 to 1. The voltage is also brought down from 2 to 1 (10 volts to 5). A transformer works in the simple way we have described (Fig. 265). There are step-down and step-up transformers. Step-down transformers bring down the voltage; step-up transformers raise it. The voltage can be brought down by using a smaller number of turns of wire in the second coil; it can be raised by using a larger number of turns of wire in that coil.

A big generator at Niagara Falls sends out electricity at a pressure of 2,200 volts. This pressure (2,200 volts) must be raised to a greater voltage, or pressure, to send a current of electricity to distant cities. Therefore, the pressure may be raised to 22,000 volts by a transformer and sent through wires to Buffalo, let us say. To raise 2,200 volts to 22,000, you would use a transformer in which the number of turns in the second coil is 10 times as great as the number in the first coil (22,000 volts is 10 $\times$ 2,200). Suppose you wanted to bring the voltage down from 22,000 to 2,200 volts. You would use a step-down transformer in which the first coil has ten times as many turns of wire as the second coil. Then to use the current at home you might use a second transformer to bring the 2,200 volts down to 110 volts. How would you do this?

$$\frac{2{,}200 \text{ volts}}{110 \text{ volts}} = \frac{20}{1}$$

265 *1*, a step-down transformer. Can you explain why the voltage in the second coil is one-half that in the first? *2*, a step-up transformer. Why is the voltage in the second coil twice that in the first?



Thus you would use a transformer with 20 times as many turns of wire in the first coil as in the second.

Next time you see the black boxes on the poles carrying electric wires you will know them as transformers. We now know that the voltage of the current which the transformer puts out depends upon the number of turns of wire in the two coils. If the number of turns of wire in the second coil is greater, the voltage of the current is raised; if it is less, the voltage is brought down.

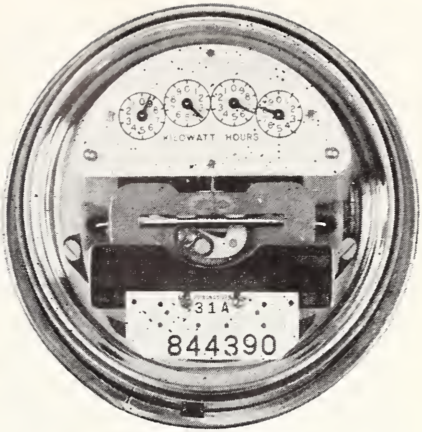
How to Read a Meter

Like most forms of energy, electricity must be paid for. Electric power companies charge for the electricity they send you. They measure the power you use in *kilowatts.* A kilowatt is a thousand watts. Each user of electricity is charged for what he uses by the kilowatt-hour.[1] Have you ever looked at your family electric light bill? If you haven't, ask your parents to let you look at it to find out how much electric energy in kilowatt-hours your house or apartment used this past month. Compare it with the amount used at other times of the year.

Electric power companies use meters to measure how much electric energy a home uses. Do you know how to read a meter? Here is how it is done.

You will notice that your meter has four dials (Fig. 266). Each dial is numbered from 0 to 10; that is, up to 10 kilowatt-hours. From right to left, this number of kilowatt-hours (from the first dial) is multiplied by 10 for each dial; that is, the second dial from the right reads from 10 to 100; the third from the right 100 to 1,000, and the fourth from the right, 1,000 to 10,000. In reading a meter, take the left-hand dial first and read the figure last passed by the pointer. Do the same for each dial as you go from left to right. The result is the total number of kilowatt-hours used by your home since electricity first flowed through the meter. Read your meter each day for two days. You will get an idea of how much electricity you use daily.

[1] A kilowatt-hour equals 1,000 watts an hour.

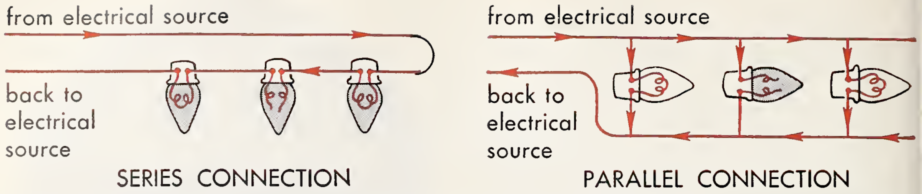


CONSOLIDATED EDISON CO. OF NEW YORK

266 A modern electric meter for a home. How does it show that 9,368 kilowatt-hours of electric energy have been used? *Project:* Try to read your meter at home. Check your reading with your electric light bill.

Electrical Connections

Have you used Christmas tree lights that were connected in *series* (Fig. 267)? Then you know that when one light goes out, all go out. That happens because the complete electric circuit is broken by the broken filament of one light. For this reason, series connections are not often used in wiring houses. However, they are used in connecting dry cells to multi-



267 *Left*, if one light goes out, all lights go out. Has this happened to your Christmas tree lights? *Right*, if one light goes out, other lights remain lighted. If you have had to replace a bulb recently, were other lights still on in your home?

ply the power of one dry cell by the number of cells so connected (Fig. 268). Thus in your flashlight each dry cell is connected in series with the next so as to make the power of the light greater.

Parallel connections are used in wiring homes (Fig. 267). Thus if one light goes out, the others will still light because a complete circuit is not broken for the others. Each electric appliance (like a lamp or radio) is connected as if it had its own circuit. When the appliance is turned on, it makes a complete circuit by itself.

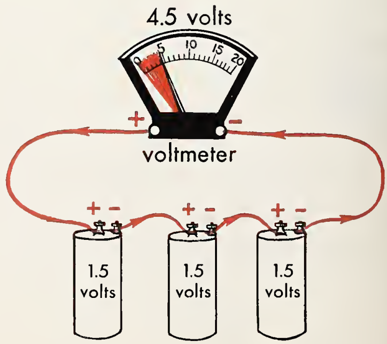
The use of parallel connections, however, causes more electric current to flow through the house wiring as each light or electric appliance is turned on. Again you may compare this flow of current to a flow of water through pipes. The more pipes — or connections between the pipes — to carry the flow, the more flow is needed to fill the pipes. The larger the size of each pipe, the easier it is for the flow of water to pass through.

So it is with electricity. Wires carrying a current of electricity through a house must be thick enough to carry the flow of electricity safely, even if all the lights and other electric appliances are turned on at the same time. The thinner the wire, the harder it is for a large number of electrons to flow through it. Another way of saying it is that a thin wire resists the flow of electrons. The thinner the wire, the greater its *resistance* to the flow of electric current. This resistance causes heat.

Handling Electricity Safely

Many fires are caused by faulty wiring of houses, either by using unprotected wires or wires too thin to carry the flow of current. Wires carrying electric current must be carefully insulated: that is, they must be covered with something like rubber which does not conduct electricity. When the insulation is broken, the unprotected wires may start a fire. Also when the insulation around a wire is frayed and the wire is bare to the touch, there is great danger of injury. The electric current may go

268 Three dry cells connected in series. Why does the voltmeter show 4.5 volts?

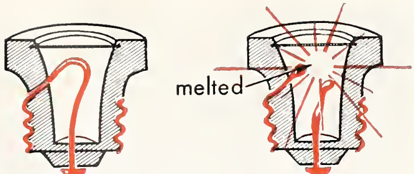


through the body instead of through the wire. Never touch a frayed wire unless the plug is first removed from the wall socket.

There are safety devices called *fuses* which break the electric circuit when the circuit is "overloaded." A circuit is overloaded when too much current enters it. Fuses are placed in metal boxes, and the incoming current passes through low-melting alloy wires in the fuses (Fig. 269). The heat (due to the overloading of electric current in the wires) melts the fuse wire, and the connection is broken. Overloading the circuit is caused by using too many electric appliances on the same circuit or using appliances that call for more electricity than the wires can carry safely. Then the fuse "blows"; that is, the alloy wire on the fuse melts when there is an overloaded circuit.

In the ordinary circuit, electric current goes from its source to an electric appliance, say a lamp, and back to its source. A short circuit is caused when two bare wires carrying electricity to and from your lamp touch each other. Instantly a large electric current finds an easy path back to its source. The heat in the wires becomes so great that the bare copper melts and sparks fly where the wires touch. However, the heat also melts the wire of the fuse. The cause of the short circuit must be removed and the right fuse replaced before you again have electricity in that circuit. It is important, therefore, that all cords to electric appliances be examined often and replaced as they become frayed. Do not wait for a short circuit.

It is even more important that you and the members of your family know and follow certain safety rules. Many



269 What happens when a fuse "blows"? What causes it to blow? Where are the fuses in your home wiring system located?

deaths are caused because these safety rules are overlooked. It is well worth repeating them — and obeying them, for your very life may be at stake.

Rules for Dealing with Electricity

1. Never touch a bare wire carrying an electric current.

2. Do not put your finger into any electric socket.

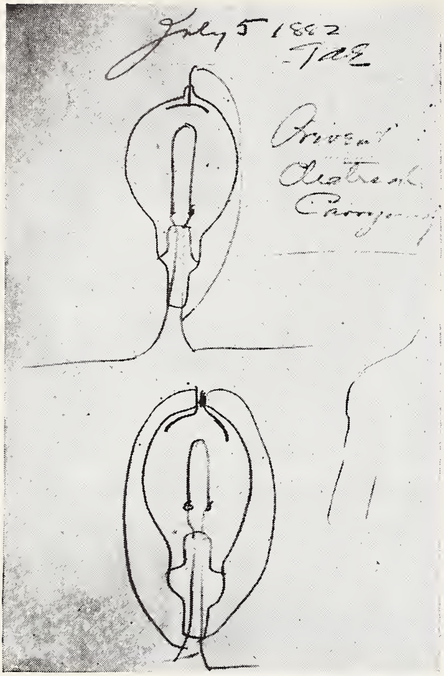
3. Do not turn on an electric light or handle an electric appliance when your hands are wet. You may get a "short circuit" through your fingers or body.

4. Do not, while in the bathtub, turn on a switch or handle an electric appliance. This is extremely dangerous. The electricity may go through your entire body. And do not have a radio in the bathroom.

5. Never leave an iron, toaster, electric heater, or any kind of heating appliance "on" when you leave the house. These may cause a fire.

Light from Electricity

Thomas Edison was the first scientist to get useful and practical light from electricity. He had many prob-



THOMAS ALVA EDISON FOUNDATION

270 Edison's drawing of one of his many attempts to make a practical electric light bulb. Note his initials. How are your home light bulbs different from this one?

271 Light from electricity produces this breath-taking skyline of New York City at night.

lems to work out. First, he needed something as fine as a thread that would heat up and glow when electricity was passed through it. Also, he wanted a filament, as he called it, that would not melt even at this heat. He finally found the answer to his problem by baking a piece of cotton thread in an oven until it became a thread of carbon. The oxygen in the air would cause this carbon thread to burn if he heated it red-hot in air. He solved this problem by sealing the filament in a globe of glass from which he had pumped out the air.

He also found a way to connect the ends of the filament to a base in the bulb so that when the base was put into a socket, a complete electric circuit was made. So Edison invented the base of the bulbs you buy today.

How are today's light bulbs different from those invented by Edison? Not too much (Fig. 270). In fact, except for using (1) coiled tungsten in place of carbon filaments, (2) frosted globes to give a softer light, and (3) a gas such as argon to give a longer life, they are the same. Modern factories turn out millions of bulbs for every bulb that Edison made by hand (Fig. 271).

J. WALKER GRIMM

Most of the energy of the electric current flowing through an electric light bulb, unfortunately, is used in making heat instead of light. For example, you cannot hold your hand on a 60-watt bulb that has been lighted even a short time. The loss of electric power through its change into heat has led to wide use of the fluorescent (floo-er-ESS-unt) tube or lamp. The fluorescent tube gives off more light with less use of electricity than does the electric bulb. More of the electricity in the fluorescent tube is used in giving light. These tubes cannot be screwed into an ordinary electric socket, but need a special connection to the electric circuit.

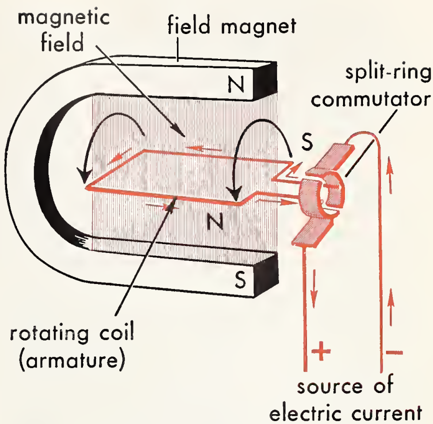
Useful Heat from Electricity

You have learned that some metals like copper conduct electricity easily. Other metals, like tungsten in a lamp filament, offer great resistance to a flow of electrons and become red-hot. One metal that gets red-hot as soon as electricity flows through it is nichrome (NY-krohm) (an alloy of nickel and chromium). Nichrome wires are used in electric toasters, irons, and stoves. In this and other ways we get useful heat energy from electricity.

Power from Electricity

Look around your house. Are there any appliances that "run" by electricity? Have you an electric sewing machine, cake mixer, washing machine, vacuum cleaner, refrigerator, fan, deep freezer, or oil burner? Then you know how useful electric power can be in running appliances that make your home a more comfortable and convenient place in which to live.

A SIMPLE MOTOR



272 This is how an electric motor runs. A coil of wire carries an electric current which throws out magnetic lines of force. Each side becomes a north or a south pole, depending on the turn of the split ring. At the same time the field magnet with its opposite north and south poles attracts first one side of the coil of wire (armature) and then the other side. An electric motor has thousands of turns of wire in the armature, and it has a large magnetic field. With pulleys or gears attached to the shaft of the armature, electric motors run machines. Which machines in your home are run by an electric motor?

Electric power is used not only in the home. The motors that run the great machines of industry, that turn the propellers of the largest ocean liners and the wheels of monster locomotives are run by electricity just like the motors in your home.

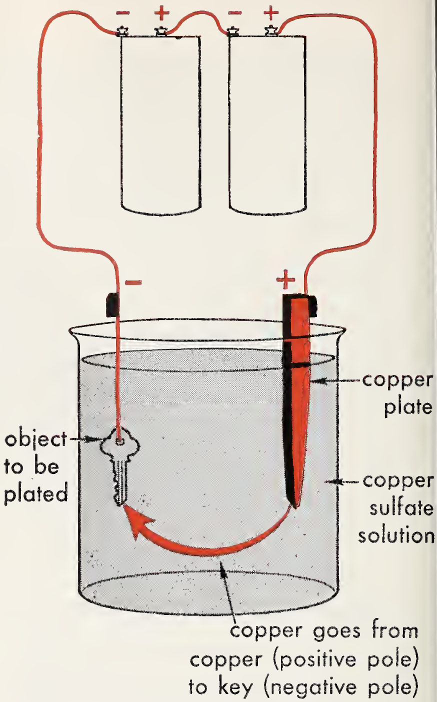
Electric motors are usually built to run by using either direct or alternating electric current but not both. They are marked DC or AC on the outside. However, many motors are built to run equally well on AC or DC. Electric motors are like electric generators in that they have similar parts, such as armatures, and mag-

nets surrounding the armatures (Fig. 272). The main difference between them is that in generators the armatures are turned by mechanical energy to make electricity, while in motors electricity is sent into the armature to make mechanical energy. Thus if the armature of a DC motor is turned by mechanical energy, it can be used to make electricity.

Electric motors are made to run by electromagnetism. In the center of the motor there is an armature mounted on a shaft which is free to whirl. The armature is made of coils of wire. An electric current is passed through the coils of wire in the armature, making them electromagnets. These coils, like all electromagnets, now have north and south poles (Fig. 272).[1] Each north pole in the armature is attracted to a south pole in the surrounding magnetic field. Each south pole in the armature is attracted to a north pole in the surrounding magnetic field. This attraction causes the armature, which is attached to a shaft, to turn over and over. Study Fig. 272 as you reread the paragraph above.

The power of electric motors is often taken from them by a pulley attached to the shaft of the armature. This pulley is connected by a belt to another pulley on the shaft of a machine. Electric motors vary in power output from the smallest, about 1/1,000 horsepower, to giants the size of an ordinary room, which make over 40,000 horsepower. Electric motors do not waste much of the energy of electricity. Where electricity is easily available they have replaced other ways of making power.

[1] In most motors an electric current is also passed into coils that surround the armature.



273 In plating objects with copper, silver, or gold, you must have a positive pole made of the metal. You must have a negative pole, the object to be plated. You must have a solution of the salt of the metal. Here, it is copper sulfate. As the current of electricity flows from the positive copper pole to the key, pure copper is plated on the key.

Endless Uses of Electricity

In this chapter there is not enough space to mention all the uses of electricity. But we can mention a few of the more common ones. Have you wondered how bright chromium finish is put on automobile trim and bumpers? Or how your silverware was plated with silver? This is done by a process called electroplating.

Suppose you want to plate a sheet of metal with copper. You will

need a source of electricity, a positive and a negative pole, and a solution containing copper, generally copper sulfate. The electric current can be supplied by two dry cells. The positive pole is made of copper and is connected to the positive pole of one of the dry cells. The negative pole is the sheet of metal you wish to plate with copper. It is connected to the negative (or side pole) of one of the dry cells. When the copper pole and the object you wish to plate are placed in the copper sulfate solution, an electric circuit is completed from the positive pole through the copper sulfate solution. The copper in the solution is deposited on the metal sheet and is replaced by copper from the positive pole. After a certain length of time, a thin film of copper covers your metal sheet. It has been electroplated. In much the same way, printers make copper plates for printing books. This page you are now reading was made by electroplating.

There are many other uses of electricity. For instance, X-ray machines run by electricity take pictures of the skeleton and internal organs of the body. X rays are also used in the treatment of cancer and other diseases. Neon signs, television, radio, telephone, telegraph, movies — the useful or entertaining things that depend upon electricity — are many. Electricity is indeed one of man's most useful servants.

LOOKING BACK

Tool Words

To be sure you understand the key words below, write the statements in your notebook and replace each blank with the correct word from the list. DO NOT MARK THIS BOOK.

static electricity	field	generator
current	series	ampere
storage battery	parallel	direct current
dry cell	alternating current	armatures
circuit	volt	attract
electromagnet	kilowatt-hour	repel
lines of force	short circuit	

1. Electricity made by friction is called . . . .
2. Like charges of electricity . . . each another, while unlike charges . . . each another.
3. A flow of electrons through a conductor is called . . . electricity.
4. When an electric current flows from its source back to its source, it makes a complete electric . . . .
5. A . . . furnishes electricity for the lights and starters of an automobile.
6. A source of electricity that has an outer covering of zinc is the . . . .

7. A current of electricity that flows first in one direction and then another is called . . . .

8. The . . . is a unit for measuring the pressure of electricity.

9. Like magnetic poles . . . one another; unlike poles . . . one another.

10. The lines of force around a magnet are called a magnetic . . . .

11. Electric current is made when . . . are cut by coils of wire.

12. When electricity flows through a coil of wire wound around an iron core, an . . . is made.

13. When a fuse "blows" in your home, it is usually due to a . . . .

14. Connections in . . . are used in wiring houses.

15. A thousand watts of electric power used in one hour is called a . . . .

16. Connections in . . . are used in batteries for your flashlight.

17. Electric generators and electric motors have . . . , field magnets and rings that rub against brushes.

GOING FURTHER

In the Laboratory and Field

1. *Charging a balloon.* Blow up a balloon and hang it from a support. Rub the balloon briskly with a piece of woolen cloth or fur. If your fountain pen is made of plastic or rubber, rub it briskly with the wool or fur. Bring the pen near the balloon. What happens? Take a glass rod (a glass towel rack or the insert to a Silex coffeemaker will do) and rub that with a piece of silk. Bring the rod near the balloon. Is there attraction now? Remember that the rod is now charged with positive electricity and the fountain pen was charged with negative electricity. What charge is on the rubber balloon? How does this experiment help you to understand the simple electrical law concerning charges of electricity?

2. *Examining a dry cell.* Open a dry cell by carefully breaking the top. Examine the contents. Find the following: the carbon pole; the mixture of manganese dioxide, ammonium chloride, and carbon; the paper lining; and the zinc container. Are the insides really dry?

3. *Building an electric motor.* Send to Westinghouse Electric Corp., 306 Fourth Ave., Pittsburgh (30), Pa., for the booklet, *How to Build an Electric Motor.* You can build this motor by using a few nails and some wire. After you have built the motor, connect it to two dry cells. Can you explain why it runs?

Put on Your Thinking Cap

1. Two rubber balloons are blown up and hung from a support so that one inch of space separates them. Each one is rubbed with a piece of fur. Will the balloons now (*a*) come together, (*b*) swing farther apart, (*c*) remain as they are?

2. You move the floor lamp from one position in a room to another. As you push the plug into a socket, you notice that the cord appears frayed near the plug. When you move your lamp nearer your chair, suddenly all the lights in the room go out. Where would you look for the cause of the "short circuit"? What would you do to (*a*) make your floor

lamp light again, (*b*) make all the rest of the lights in the room light up?

3. Which would you think costs less to use, a 60-watt lamp burning 12 hours or a 40-watt lamp burning 20 hours? (A kilowatt-hour is 1,000 watts per hour.)

4. If you were wiring a Christmas tree, would you use series or parallel connections? Why?

5. Wheat is ground into flour by machinery which would be injured by the metal articles such as nails, screws, and bolts often found in carloads of wheat. Can you think of an easy way to take metal articles out of the wheat?

Adding to Your Library

1. *All About Electricity* by Ira M. Freeman, Random, 1957. This book is packed with interesting ideas for boys and girls who want to experiment with electricity.

2. *Understanding Electronics* by John Lewellen, Crowell, 1957. If you want to find out more about magnets and electricity, try this up-to-date and clear book.

3. *First Electrical Book for Boys* by Alfred Morgan, Scribner, 1951. You'll enjoy this book full of exciting electrical experiments you can do.

4. *Picture Book of Electricity* by Jerome S. Meyer, Lothrop, 1953.

5. *700 Science Experiments for Everyone* compiled by UNESCO, Doubleday, 1958. In the section on magnetism and electricity you will surely find experiments you'll want to try.

6. *First Book of Electricity* by Sam and Beryl Epstein, Watts, 1953.

7. *Things Around the House* by Herbert S. Zim, Morrow, 1954. Doorbells, electric lights, refrigerators and faucets; find out how they work from this book.

A Bit of Research

If you use electricity in your home, it comes from some source. Find out where that place is, how the electricity is made, and how it gets into your home.

Careers for You

Do you want to join the men and women who make electricity work for you? The electric light, telephone, radio, and television companies and their laboratories need trained people. The manufacturers of electric washers, refrigerators, stoves, and other electric appliances need not only trained people but also people who can design and invent better ways to make electricity a better servant.

Electrical engineers are always needed by industry. They are the persons who know where and how electricity should be used to get power cheaply; they plan the miles of electric wiring in a jet plane; they make improvements in radar, radio, and television. Why not be an electrical engineer?

CHAPTER 25

Modern Pack Horses

How far from New York to Los Angeles? About 3,000 miles. This isn't the whole answer. It is about five hours by modern jet airliners. The world has shrunk because of the modern "horse" in horsepower.

Do you think anyone could travel around the world in fifteen hours — travel at the speed of almost 1,500 miles an hour? Actually an airplane has flown 1,650 miles an hour, nearly twice the speed of a rifle bullet. If this pace could be kept up, the airplane could fly from New York to San Francisco in less than two hours, and around the world at the equator in about fifteen hours. But this speed could not be kept up.

To reach this great speed, the airplane used rocket engines. These engines work somewhat on the same principle as the skyrockets you see shooting into the air in fireworks displays. Also like skyrockets, rocket engines burn up their fuel very quickly. That is why airplanes using rocket engines cannot keep up their speed for more than a few minutes. That is also why the airplane mentioned above could not fly around the world in fifteen hours.

Ever since man learned that he could run faster than he could walk, he has been finding new ways to travel faster. From your reading in Unit 3 you know it is quite possible

that some day man may travel clear of the earth's envelope of air in rockets at speeds of thousands of miles an hour, if the rocket fuel gives enough thrust. In this chapter, however, we shall deal with travel on land, on the sea, and in the air. You will learn that it is not just by accident that a train has certain kinds of rails or that an automobile has gears. You will learn why a ship floats on water and why a submarine can rise or sink. You will learn why an airplane has wings and how a jet engine works. You will learn how modern science is always finding better ways and cheaper ways to get you where you want to go speedily and safely.

ON LAND

You may not know who the Duryea (DER-yay) brothers were, but they certainly had a hard problem to solve in 1892. They were building the first automobile.

The First Automobile

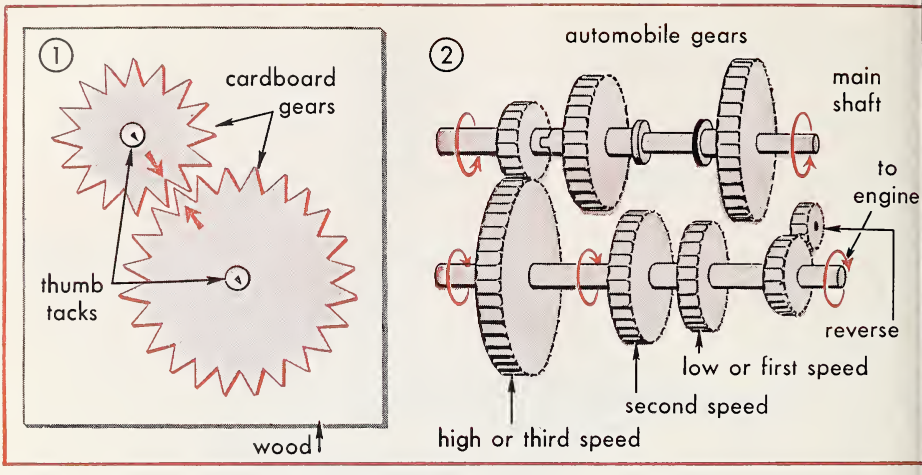
In your study of the gasoline engine on pp. 465–467 you learned that its power turns a shaft on which may be pulleys or gears that run other machines. The Duryea brothers had the problem of making the shaft of their engine turn the wheels of a wagon whenever the driver wanted to move. So they invented the "clutch." By pushing a pedal of the clutch, they were able to connect the power of the engine to the rear wheels or to disconnect it. The rear wheels were connected to the clutch by a chain, which ran over gears, as does the chain on a bicycle. When the driver used the clutch, the engine caused the chain to move the rear wheels. The first successful run of the Duryea automobile took place in 1892. That year was the beginning of the automobile age.

The Modern Automobile

Modern automobiles do not look very much like the first ones. The modern engine has four to eight cylinders and is powerful and smooth-running. The engine is connected to the rear wheels by gears, which make the rear wheels move. These sets of gears, called the *transmission* and *differential* (dif-uh-REN-shul), help the engine turn the rear wheels and make the car move forward or backward.

You can find out how gears work by looking at your bicycle. Bicycle gears work somewhat like the gears of an automobile. For example, you turn a large gear by pushing on the pedals. A chain joins this large gear to a small gear on the back wheel. When you turn the large gear once around, the small gear moves the back wheel many times around.

You can show this action by cutting out two round pieces of cardboard 8 inches and 2 inches in diameter and making notches or teeth around the outside of each. Fasten these cardboard gears to a piece of wood by thumbtacks placed through their centers. Make sure that the teeth of one gear fit into the open spaces between the teeth of the other gear (Fig. 274). Make a mark with a pencil on one of the teeth of the larger gear and also mark the place where the tooth rests between the two teeth of the smaller gear.



274 *1, Project:* Make two cardboard gears, as in the drawing. Follow the directions on p. 503. Why is a large gear attached to the pedals of your bicycle? *2,* an automobile transmission. The bottom shaft, with gears, is turned by the power of the engine. The top shaft, with gears, turns the rear wheels. How do you know that the automobile is in high, or third, speed?

Now turn the large gear around once. How many times around does the small gear turn? Does this show why you can go so fast on a bicycle even though you turn the large gear slowly with the pedals?

Place the marks on the gears opposite each other again. Turn the small gear around once. How far does the large gear turn? If the small gear were attached to the pedals of a bicycle and the big gear to the rear wheel, would it be easier for you to ride up a steep hill? Would you go very fast?

Small and large transmission gears of an automobile are shifted so that the car can go at different speeds with different changes of power. In many cars the gears can be shifted by a gear-shift lever that is on the steering wheel column. You can see how a gear-shift lever works in Fig. 274.

The rear wheels of an automobile are connected directly to the differential gears. These gears allow one of the rear wheels (the inside wheel when turning a corner) to turn more slowly than the outside wheel. Otherwise the wheels would be badly damaged.

The power of the engine can be stopped from going through the gears to the rear wheels by pushing down on the clutch pedal and using the gear-shift lever to separate the transmission gears.[1] This action is called "shifting into neutral" (Fig. 274). When the driver pushes down the pedal of the clutch with his left foot, he keeps the power of the engine from moving the rear wheels. When he removes his foot from the pedal, he lets the power of the engine move the rear wheels, if the gear shift is not in neutral.

[1] In most modern cars the gears change by themselves according to the speed that the car is moving and according to the power that is needed. This is called "automatic shift."

Getting Ready To Drive

No doubt you are looking forward to the time when you can get a license to drive an automobile. In most states boys and girls must be sixteen years old before they can get a driving license. They must take a driving test with an inspector and pass a written or oral test on driving regulations.

You are not of age now, but soon you will be able to get ready for this test. Your state registry of motor vehicles probably can send you a booklet on motor-car rules and regulations. It will tell you everything you must *know* and *do* if you are to drive a car in your state. Perhaps your high school has a driver training course that you can take. At the end of the course, if you are sixteen, you take the tests for your driving license.

Until you get your license *do not drive an automobile unless a person who has a license to drive is sitting beside you.* In most states there is a heavy penalty for not obeying this warning.

A Safe Car

Brakes and lights are the most important safety features of modern cars. In 1912, the first automobile with electric lights and a starter was made. It was not until 1924 that automobiles were given four-wheel brakes. To be able to come to a stop quickly and to see at night are so necessary for safe driving that many states make car owners have their brakes and lights examined twice each year. If your family has a car, find out when its brakes and lights were last examined. *A safe car has good brakes and good lights.*

Safety on the Highways

In 1894, there were only 30 automobiles in the United States. You can see that there must have been few traffic accidents then. Today there are over 50 million automobiles and over 20 million trucks on the nation's highways. In 1953, over 38,000 people were killed and more than 1¼ million were injured in automobile accidents.

Most automobile accidents are caused by careless driving. Some are caused by careless walking, such as crossing in the middle of busy streets. Remember that the average modern

275 Although the automobile was not going over 35 miles an hour, note what happened to it when it skidded on the wet road and struck the bus.

AMSTERDAM (N.Y.) "RECORDER"

car weighs over 3,000 pounds, and is capable of speeds of over 80 miles an hour. Even at 35 miles an hour it has a great amount of energy. At this speed it has a striking force of over 156,000 foot-pounds. Such force is more than enough to break off a telephone pole or a small tree, or to kill a person walking (Fig. 275).

Moreover, if a car moving at 35 miles an hour strikes a tree or a pole, the car stops at once, but the passengers don't stop. They keep on moving forward at 35 miles an hour. Do you wonder that persons are thrown through windshields and that the driver's body often breaks the steering wheel in accidents of this sort? And 35 miles an hour is a rather low speed with the modern automobile. The greater the speed, the worse the effect when objects are struck. Can you see what happens when a person drives carelessly at a high speed on an unsafe highway? He may be the cause of one or more of the yearly million and a quarter deaths or injuries that happen each year from automobile accidents.

Automobiles and trucks are needed for our everyday living. Indeed, large parts of this country do not have any other means of travel. The automobile lets people build homes far from bus and railway lines. Doctors can reach patients quickly; firemen can rush their fire trucks to fires quickly; and police can protect large parts of towns and cities with only a few men. Trucks carry food swiftly and smoothly over our 3 million miles of road. Nearly everything you use each day has been carried all or part of the way to you by trucks. Without automobiles and trucks our life today would be very difficult.

276 The modern T rail. Why does it have this shape?

PENNSYLVANIA RAILROAD

The Steel Rail — Gift of Engineering

Though we need trucks, we need trains even more. They carry materials for industry. Most of our big industries would shut down in a short time if railroads stopped carrying heavy freight.

The next time you go to a railroad station or walk across railroad tracks, look closely at the rails. In cross section a steel rail is T-shaped, with a broad base and narrow top (Fig. 276). This T-shaped rail is the result of a hundred years of study and experiment. The first rails used for trains were made of wood, with iron bands fastened to the top. From these first rails to those used today, there have been seventeen kinds of rails made. The top of the modern rail is

UNION PACIFIC RAILROAD

277 Diesel engines like the one above have replaced steam locomotives on many railroads.

made to fit and hold the flanges (FLAN-jez), or overhanging sides of the car wheels. The stem of the T is so strongly made that it will not bend too much or break under tons of weight passing over it. At present no other kind of rail can do this better. The rail seems very simple, but years of research were needed to make it.

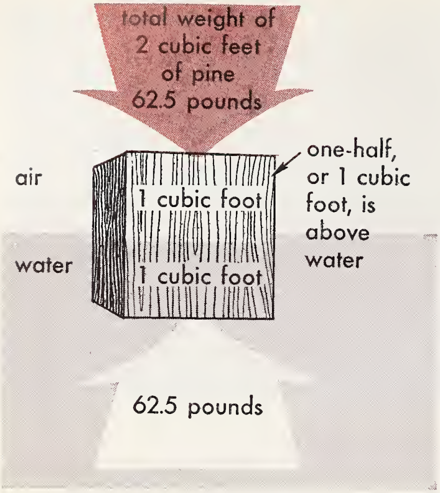
In 1832, there were only 40 miles of railroad in the United States; in 1861, 30,000 miles; in 1880, 94,000 miles, and today over 400,000 miles of steel T-track carry each year a billion passengers and 2½ billion tons of freight.

The Modern Railroad Train

Modern railroad engines are very much different from Stephenson's first engine, or from the engines that drew trains in 1861, in 1880, or in 1905. The fastest recorded run by a locomotive was made in 1905 at 127 miles an hour at Elida, Ohio. This run, however, was a test speed run over three miles of straight track. Modern locomotives do not make such test runs. To prevent accidents, the fastest modern locomotives average, with stops, little more than 60 miles an hour over long distances. Many of these locomotives draw streamline trains with cars joined together so that the entire train seems to be one unit. Some trains have observation cars with glassed-in roofs. Many have the comforts of the best hotels.

Railroads are always trying to find better and cheaper ways to run their trains. Because the fuels are cheaper than coal, engines that burn gasoline or kerosene have been used on short runs. Electric engines that have no fumes or smoke are often used to draw trains through large cities.

Today, Diesel engines using oil for fuel are replacing the steam engines that used coal (Fig. 277) because they are cheaper to run. These Diesel engines give power to generators which in turn send a current of electricity to motors. These motors, geared to the wheels of the engines, pull the trains swiftly along. Some engineers predict that Diesel engines may soon replace coal-burning engines. Others are not so sure.



278 The 2-cubic foot pine block is buoyed up in water by a force of 62.5 pounds. Why does one-half of the block float above the surface?

ON THE SEA

Only 150 years ago, the first steamboat, with sparks and smoke belching from its stack, chugged along against wind and tide. No longer would men have to wait for a favorable wind or tide to take them out of harbors. Today great steel ships weighing thousands of tons go to all the harbors of the world. Although some are powered by Diesel engines, most of these ships use the power of steam to turn high-speed turbines. These turbines are often connected by gears directly to the propeller shafts. On very large ships the turbines turn generators which send electricity to motors that turn the propeller shafts. In the largest ocean liners each propeller is turned by a 40,000-horsepower electric motor. Remember that 40,000 horsepower means the equivalent of the powerful pull of 40,000 horses!

How Does Water Support Ships?

Over 2,200 years ago, Archimedes (ahr-kih-MEE-deez) found that objects seemed to weigh less in water than in air. Archimedes also found that any object placed in water displaced or pushed aside some of the water. You can make the same findings if you fill a glass brimful of water and carefully drop a stone into it. Some of the water overflows. But Archimedes went further. He knew that objects seemed to weigh less in water. He weighed the water that overflowed. He found that the weight of the overflow water just equaled the weight that the object lost when placed in water. After many experiments he wrote a statement about his work. The statement is known today as Archimedes' principle. It is this: Any object placed in a liquid is pushed upward by a force equal to the weight of the liquid displaced by the object.

An object will float on water if it displaces an amount of water equal in weight to its own weight (Fig. 278). A tiny, heavy object does not displace much water. Since it is heavier than the water it displaces, it sinks rapidly.

Suppose you had a block of dry pine wood, 2 cubic feet in volume, which weighed 62.5 pounds. If you put this block of pine into water, it would sink only halfway under and then float. The 1 cubic foot of wood below the water surface has displaced 1 cubic foot of water. One cubic foot of water weighs 62.5 pounds. The wood is thus held upward by a force equaling its own weight (Fig. 278). But the volume of the pine block is 2 cubic feet. So one-

half of it, or 1 cubic foot, will stick up above the surface of the water. This is so because the entire block (2 cubic feet) is only half as heavy as the weight of 2 cubic feet of water. From this, it is easy to see why an empty rowboat floats higher in water than does one with people in it.

Why Does a Steel Ship Float?

You see now that an object floats when its weight is less than the weight of an equal volume of water. An object sinks when its weight is greater than the weight of an equal volume of water. Any object that sinks displaces a volume of water equal to its own volume. If 1 cubic foot of steel weighing 500 pounds is placed in water, it will displace a cubic foot of water weighing 62.5 pounds. Since its weight is eight times as heavy as the cubic foot of water, the block of steel sinks rapidly.

But steel can be made to float. How? If you were able to cut the cubic foot of steel into thin sheets, you might fasten the sheets together to make a box about 5 feet long, 5 feet wide, and 4 feet high. Your box contains $5 \times 5 \times 4$, or 100 cubic feet. Will it sink? Remember that 100 cubic feet of the steel box still weighs 500 pounds. On the other hand, 100 cubic feet of displaced water weighs 100×62.5, or 6,250 pounds, more than 12 times the weight of the steel box. So the steel box, weighing 500 pounds, is more than 12 times lighter than 100 cubic feet of water weighing 6,250 pounds. Thus the steel box floats well out of the water.

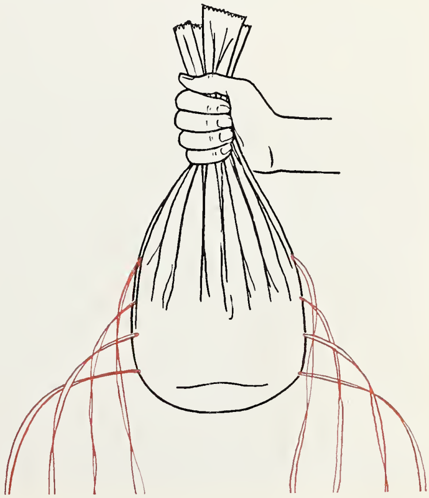
So it is that large steel ships can carry heavy cargoes. To keep people from overloading ships, lines or figures are marked on the hull of the ship. These lines show how far a safely loaded ship will sink into the water.

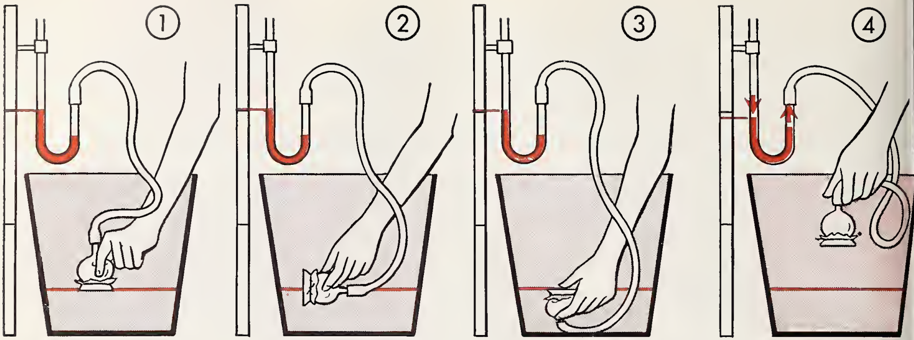
The Pressure of Water

You have learned that air presses on you from all directions at sea level with a pressure of 14.7 pounds per square inch. Two simple experiments show that water also has pressure and that this pressure is sent equally in all directions.

First, pour about 2 quarts of water into a cellophane bag. Lift the bag carefully and punch four small holes with a needle around the bag, about 1 inch from the bottom. Punch three more rows of holes, each hole 1 inch above the other around the bag. Note the force of the stream of water coming from each hole (Fig. 279). From which holes does the water spurt farthest?

279 Why do streams of water spurt farther from holes near the bottom of the bag? *Project:* Repeat the experiment. Do you get the same results? Why?





280 Water pressure, like air pressure, pushes in all directions, as in *1*, *2*, and *3*. If this pressure changes, as shown in *4*, how does it affect the level of the liquid in the U tube?

Now make a mark with a red wax crayon on the inside of a 10-quart pail, 4 inches from the bottom. Fill the pail with water and keep it filled at all times. Stretch a thin piece of rubber over the end of a short thistle tube and fasten it with a rubber band (Fig. 280). Fill the bend of a U tube with colored water and attach one end to the stem of the thistle tube with a piece of rubber tubing. Attach the U tube to a ring stand, and place the face of a ruler just behind the open end of the U tube. Push the thistle tube into the pail until the rubber-covered end is opposite the red mark. Note what happens to the water in the U tube. Since it rises as the thistle tube is pushed into the water in the pail, there must be pressure on the rubber covering. Take a ruler reading of the upper level of the water in the U tube. Turn the mouth of the thistle tube sidewise and then upward, keeping level with the red line. You will see no change in the reading of the water level in the U tube. Lift the thistle tube slowly out of the water. As the tube rises, the pressure goes down.

From this experiment you can conclude, as shown by the water level in the U tube, that at one depth water pushes with the same pressure in all directions. Does this pressure increase with depth?

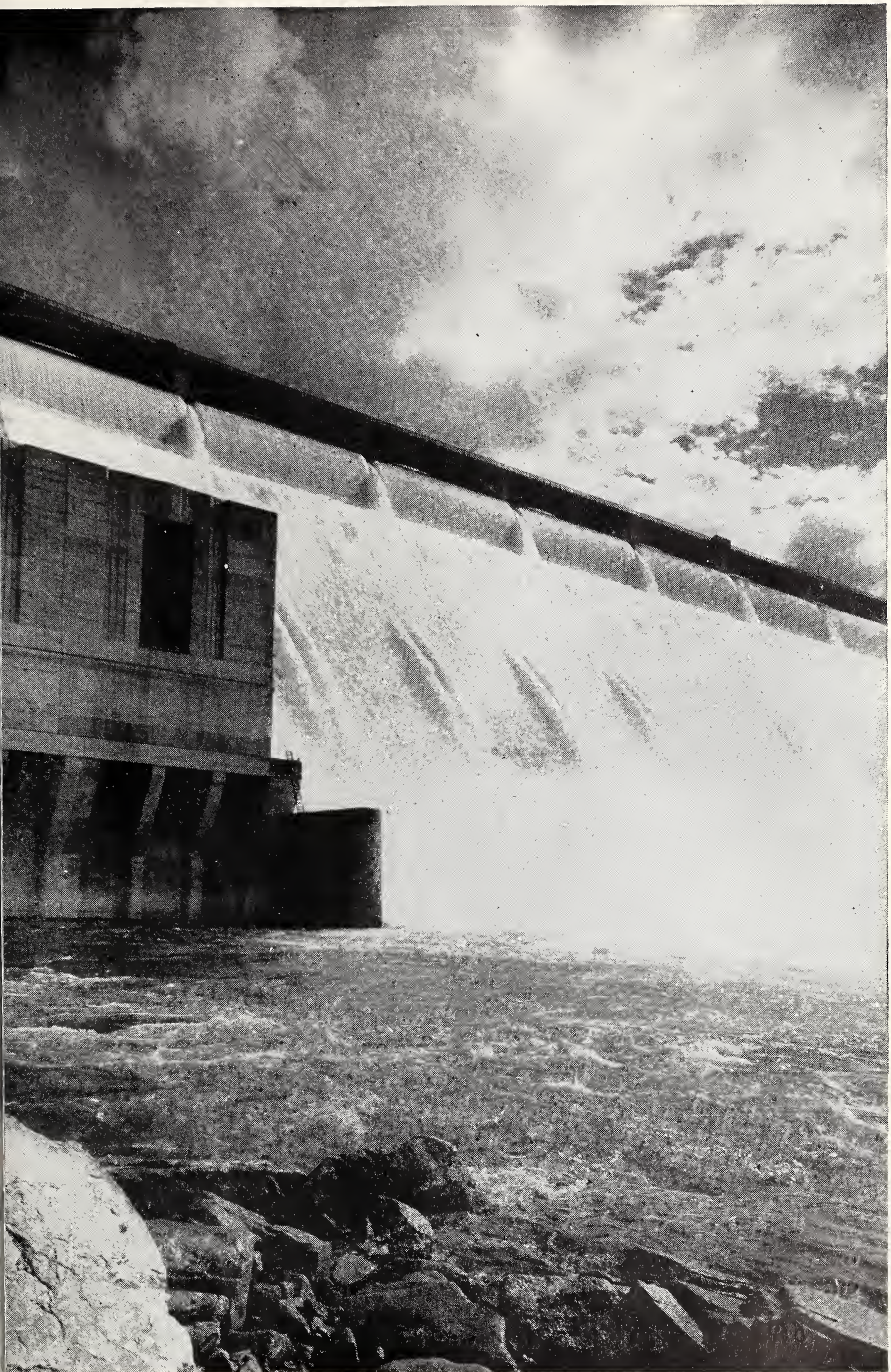
Deep Water

Actually, for about every 34 feet you go below the surface of water, the pressure is multiplied by 14.7 pounds per square inch (the amount of pressure at the surface). Even if you dive only a short distance below the surface, you can feel this increased water pressure on your eardrums. Native pearl divers of the South Seas have been known to dive to depths of over 100 feet. However, they often become deaf, crippled, or paralyzed after a few seasons of such work.

The pressure of deep water is a problem for engineers who build huge dams (Fig. 281). They must

ROBERT YARNALL RICHIE

281 The Grand Coulee Dam across the Columbia River is one of the world's longest. Why is it almost as thick through at its base as it is high?



carefully measure the thickness of the base and the strength of the concrete necessary to withstand the pressure of the water held back. For example, Hoover Dam across the Colorado River is 726 feet high. Yet it is almost as thick at its base as it is high. It gradually tapers toward the top as the need for thickness of the dam lessens with the lessening water pressure.

The pressure of deep water is also a problem for the builder of submarines. Since submarines travel below the surface of the ocean, there is a limit to the depth they can go without being crushed by water pressure. However, the hull of the modern submarine is now so strong and so well braced that it can withstand the pressure of several hundred feet of water.

Travel Beneath the Sea

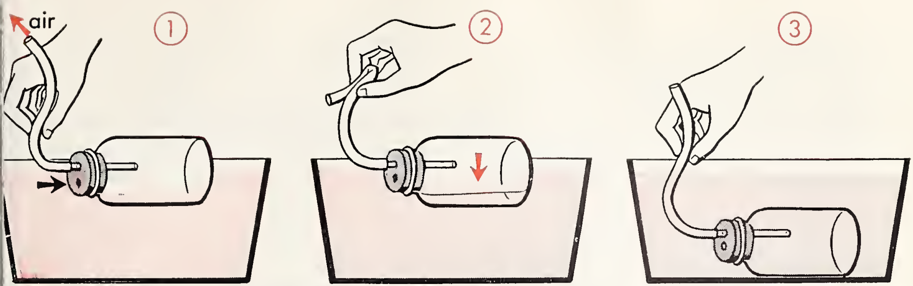
The credit for the building of the first useful submarine goes to Simon Lake and John Holland, both American inventors. In 1875 John Holland built an underwater boat 60 feet long that could sink or rise by taking in or blowing out water. Simon Lake, interested in getting treasure from sunken ships, built in 1897 the first submarine that could travel in the open sea.

On both sides of a modern submarine there are many tanks, called ballast tanks. In these tanks are huge Kingston valves that work from a control inside the submarine. A Kingston valve is like a swinging door that may be opened or shut to let water in or out of the tanks. There are also *vent* valves, like small swinging doors, at the top of these tanks. They let air out of the tanks. When the Kingston valves are open, no water can get into the tanks while the submarine is moving forward, unless the vent valves are open at the top to let air out. In other words, to let water into the tanks the vent valves must be opened to let air out of the tanks.

To run the submarine with most of it under the surface, ready for a "crash dive," the Kingston valves and the vent valves are opened. Air rushes out of the vent valves as enough water rushes into the tanks to bring the submarine level with the ocean surface. The vent valves are then closed, and no more water can enter the tanks unless air is let out of the vents. In submarine language the ship is then "running on the vents." To dive quickly, the vent valves are opened. Then water rushes into the tanks, and the submarine goes beneath the surface as its tanks fill with water.

If the submarine did not move forward and had no way of getting the water out of its ballast tanks, it would sink to the bottom of the ocean. However, it has electric motors to run the propellers underneath the surface and compressed air to blow out the water in the ballast tanks. When the commander wishes the submarine to rise, compressed air blows the water out of the tanks. The vessel then rises to the surface.

You can show how a submarine may sink or rise by doing this experiment. Through one of the holes in a two-hole rubber stopper place a piece of glass tubing to which a piece of rubber tubing about 2 feet long has been fitted. Place the stopper in a glass bottle and then lay the bottle on its side on the surface of the water in a deep



'82 *1*, air is forced out of the bottle as water enters. The bottle starts to sink. *2*, if the rubber ube (vent valve) is closed, the bottle remains half under water. *3*, opening the vent valve rubber tube) causes the bottle to fill with water and sink below the surface. Does this show ow a submarine may ride "on the vents" or sink below the surface of the ocean? How does he submarine rise to the surface? *Project:* Make a "submarine" like the one above.

glass dish. The other hole in the stopper now allows water to enter the bottle somewhat as a Kingston valve does in a submarine. The rubber tubing acts as a vent valve.

After the bottle is one-quarter full of water, pinch the rubber tubing tightly. No more air can now be forced out of the bottle; therefore no more water can come in. Release the rubber tubing. The bottle fills and sinks (Fig. 282). Does this show how a submarine may "ride on the vents" or sink below the surface? Now blow through the rubber tube. Does the bottle rise? Does this explain how a submarine rises? Why?

Living Beneath the Sea

During World War II, most submarines had to come to the surface quite often to charge the electric storage batteries that gave the power to run the submarine beneath the surface of the sea. This charging was done by Diesel engines, which needed air to burn their fuel. These Diesel engines also ran the submarine on the surface.

It was not long before the German navy found that running submarines on the surface was very risky. After the loss of over 500 submarines, the Germans made a tube, called a snorkel, that would reach up above the surface of the sea and take in the air needed to burn the fuel used in the engines. With the aid of the snorkel some submarines stayed under water for months.

Today, using atomic engines instead of Diesel engines (Chapter 15) and using the snorkel to replace the air the crew uses up, submarines can stay under water as long as the crew can stand the strain. Perhaps in time to come, large freight-carrying, atomic-powered submarines may travel beneath the seas from continent to continent without risk of storms or shipwreck. As you know, a number of atomic-powered submarines are already in use.

IN THE AIR

Just as the oceans surround continents, so air surrounds the earth. Man has known for thousands of

years how to travel on oceans to distant places, but he has known for only a short time how to reach these places by air.

About fifty years ago, perhaps the most important telegram in the world was sent. It was important because of the news it carried: "We have done it. Succeeded in four flights, 31 miles an hour against the wind." On December 17, 1903, Wilbur and Orville Wright in Kitty Hawk, N.C., sent this telegram to their sister.

Almost no one believed the message. Many newspapers did not print the news, or they gave it only a line or two of mention. If people had known then how really important was man's first flight in an engine-driven airplane, every newspaper might have had these headlines:

A NEW AGE HAS BEGUN
FOR THE WORLD — THE AIR AGE

Even after Orville and Wilbur Wright had proved that their airplane could fly, most people believed that flying an airplane was only for those who didn't mind taking the chance of sudden death. Some people knew better. Year by year, they made planes stronger and flew them faster, higher, and longer, with greater safety. To know how they did this, you should first know what an airplane needs in order to fly.

The Parts of an Airplane

The modern airplane is very different from the one first made by the Wright brothers. Their airplane, in a way, was like a canvas-covered box kite, with two sides, or wings. Airplanes with two wings, one above the other, were called *biplanes*. Biplanes were flown across the Atlantic Ocean in 1919 by the United States Navy.

Today, airplanes are called *monoplanes* because they have one wing on each side. Some airplanes are called "flying wings" because most of the parts of the airplane are inside the huge wing. Also there is the *helicopter*, which has no wings, but whirling blades that take the place of wings.

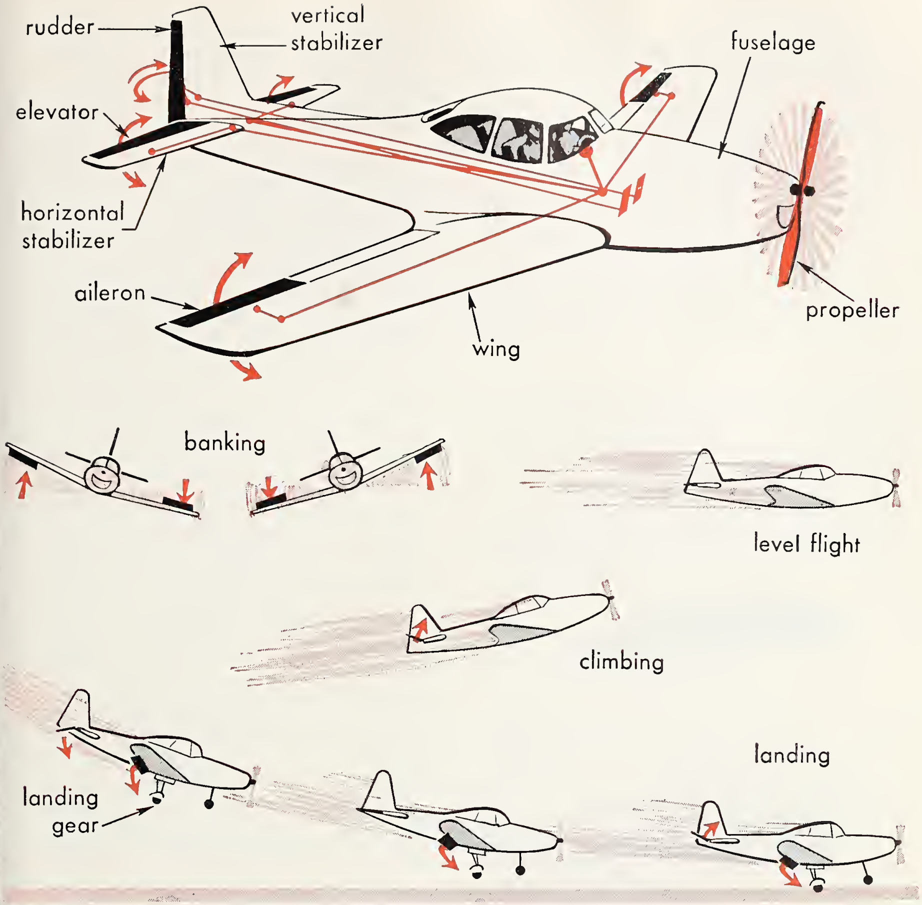
Most airplanes have certain parts in common. Examine these parts (Fig. 283) carefully before you study the following sections. Then refer to the figure as you read.

Ailerons (AY-ler-onz) are flaps placed in the rear edges of the airplane wings. When one is raised, the one on the opposite side is lowered. The push of air against the raised and lowered ailerons causes one wing to rise and the other wing to lower when in flight. This makes it possible for a pilot to "bank" or make a sharp turn with his plane. Sometimes parts of both wings, called the flaps, are lowered to slow down the speed of the plane in landing.

The body of the airplane is called the *fuselage* (FYOO-z'l-ij). In the front of the fuselage are placed the pilots' seats, controls, and instruments.

Most airplanes have *engines* and *propellers* mounted in the wings or in front of the fuselage. The engine furnishes power to turn the propeller. The propeller may have many blades, which can be turned so that they strike more air as they whirl.

Planes using jet engines do not need propellers. The engines are pushed by hot gases thrusting out from the rear of the plane. This gives them greater power with less weight than heavy gasoline engines have. Today many military and commercial aircraft have jet engines.



283 The airplane and its most important parts. How are they used in climbing, turning, diving, and landing?

Just what happens when a pilot wants to go up or down or turn to the left or right? The rudder, and all the parts that can be moved (Fig. 283), are attached to the control column or "stick" or to pedals in the cockpit. There is also the throttle which, like the gas pedal or accelerator on a car, lets the pilot control his engine. The throttle is worked by hand so that the pilot's feet are free to rest on the rudder pedals.

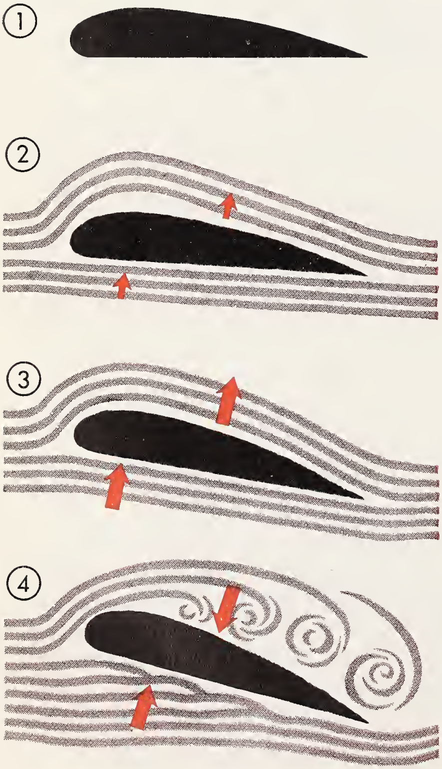
To go left, the pilot will carefully bank his plane to the left; that is, he will tilt his wings in the direction he wants to turn, much as you tilt your bicycle for taking a corner. In this position the plane will turn until the pilot straightens it out. For a right turn, the wings are tilted to the right. How is the rudder used? It only "turns" the plane in the sense that it can swing the nose from side to side. Its chief use in modern planes is to

help keep the plane going straight when rough air tosses it about, or to keep the plane from slipping and skidding as it turns.

To climb, the pilot raises the elevators (Fig. 283) and adds power by advancing the throttle. Raising the elevators raises the nose of the plane, starting it "uphill." From your own experience in going uphill by walking or riding on a bike or in a car, can you see why more power is necessary when the pilot tries to climb?

To come down, or glide, requires less power, so that as the pilot lowers the nose to glide, he usually "throttles back." If he plans to land, he will make sure his wheels are "down" (from their pockets in the wings), and he will probably lower the flaps on the trailing edges of the wings. The flaps act as brakes in the air, and slow the plane down for a smooth landing.

284 From top to bottom: *1*, the shape of an airplane wing. *2*, the faster-flowing air over the top of a wing causes less pressure above it; the slower-flowing air under the wing has greater pressure and gives the airplane lift. *3*, greater lift is given by a steeper climb. *4*, too much climb makes the air rough over the wings, lessons lift.



How Does an Airplane Fly?

If you were asked to name the most important of all the important parts of an airplane, would you name the wings? You would be perfectly right. The next time you see an airplane, look closely at its wings from the front and side. You will note that they are shaped as in the cross section (Fig. 284). If the curve of the wing is changed so much as a quarter of an inch, the way the plane flies is changed. The right kind of curve is so important that scientists have spent years of study to find the right curves for different types of planes. To help them in this study of airplane wings, wind tunnels are used. Some wind tunnels are so strong that winds of over 700 miles an hour can be made to test the wing shapes of airplanes.

The wing of an airplane strikes the air in such a way as to cause the plane to be lifted. Air meeting the curve of the upper part of the wings is swept upward and over the curved surface (Fig. 284). The air currents take the same time to pass over and under the wing, but the currents over the wing travel the longer distance and so go faster in the same time than the currents under the wing. Thus the air

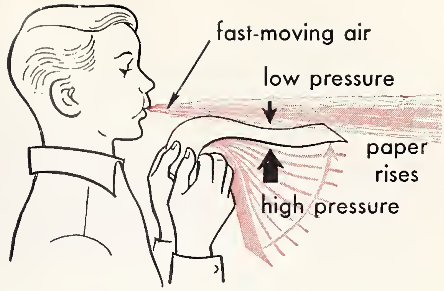
over the wing travels faster than the air under the wing.

Over 200 years ago, a Swiss scientist named Bernoulli (behr-NOOL-ee) found that in any flowing liquid the pressure lessens as the speed of the flowing liquid becomes greater. It is much the same with air. Air flowing faster over the top of an airplane's curved wing causes less pressure than does the air which flows below the flat surface of the wing. Thus, there is a higher pressure underneath the wing than above the wing. The higher pressure underneath the wing forces the wing upward. A simple way to show this is to blow over the top of a thin strip of paper (Fig. 285). Why does the end of the paper rise?

The higher pressure of air underneath an airplane's wing is known as *lift*. The lift must be greater than the weight of the plane, or the plane cannot fly.

The pilot can make the lift of his plane greater by pulling backward on his "stick." With the nose of the plane pointing upward, air flows even faster over the top of the wing, causing a lower pressure on top, and thus a greater lift. Therefore, the plane can climb rapidly.

The angle of the wing shown in Fig. 284 is called the *angle of attack*. The angle cannot be increased beyond a certain point because the air flowing over the back part of the wing "burbles" or becomes rough. When this happens, the speed of the airplane slows down and the lift quickly lessens. Of course, in order to have any lift at all, the plane must be in motion. This is caused by the propeller, which bores into the air like a screw forced into wood or like a boat's propeller blade into water. This motion is called a *thrust*. The thrust also causes the air to flow over the wings. The *drag* of the airplane which resists the thrust is the push of the air against the movement of the body of the plane. Streamlining of planes has greatly lessened drag. For an airplane to fly safely, its thrust must be greater than its drag.



285 When you blow over the top of a sheet of paper, why does the paper rise? Try it.

JET PROPULSION

Sir Isaac Newton, one of the great scientists who worked in the seventeenth century, made a study of motion. After many experiments and observations Sir Isaac published his findings, called "the Laws of Motion." His third law, which helps explain how jet-propelled planes fly, is this: "For every action there is an equal and opposite reaction."

Even the ancient Greeks had an idea of this kind. For example, they knew that steam pushed out from a container of boiling water with great force (Hero's engine, p. 455). If they had had the knowledge of later scientists, they might have built a steam carriage like the one Sir Isaac Newton invented. This had a large container of boiling water just behind the driver's seat. A valve let the steam out of a jet, facing the rear. The push

of the steam backward, Sir Isaac thought, would make the carriage go forward. But the carriage was not practical. No driver wanted a seat near the boiler — especially one that might blow up at any moment!

How Jet Engines Work

You can learn something about Newton's third law of motion by blowing up a small rubber balloon. You may also learn something about jet engines.

Blow a balloon full of air and suddenly let it go. You will see the balloon darting this way and that, finally coming to rest only when the thrust (or push) of the air inside stops coming out of the neck of the balloon.

This thrust or push from the balloon in one direction causes the same size thrust or push against the balloon in the other direction. This opposite push sends the balloon through the air.

There are three kinds of jet engines that make airplanes fly in much the same way as the toy balloon flies. They are the *turbo-jet*, the *ram-jet*, and the *turbo-prop* engines.[1]

The Turbo-Jet Engine

The turbo-jet engine has three main parts: a *compressor*, a *combustion chamber* to burn kerosene, and a *gas turbine* (Fig. 286).

The compressor starts the work of the engine. Like a fan, it blows the air backward and compresses it into the combustion chamber. In the combustion chamber an explosive fuel, like kerosene, is let loose. When the mixture of kerosene and compressed air is set afire, all the hot gases push out of the rear opening at a speed of over 1,200 miles an hour. It is the push of these gases that gives jet airplanes their great speed.

To get greater speed from turbo-jet engines, an "after-burner" has been placed behind the gas turbine. More fuel is sprayed into the after-burner, where the great heat explodes it. The push of the burned gases gives the plane a greater speed.

The Ram-Jet Engine

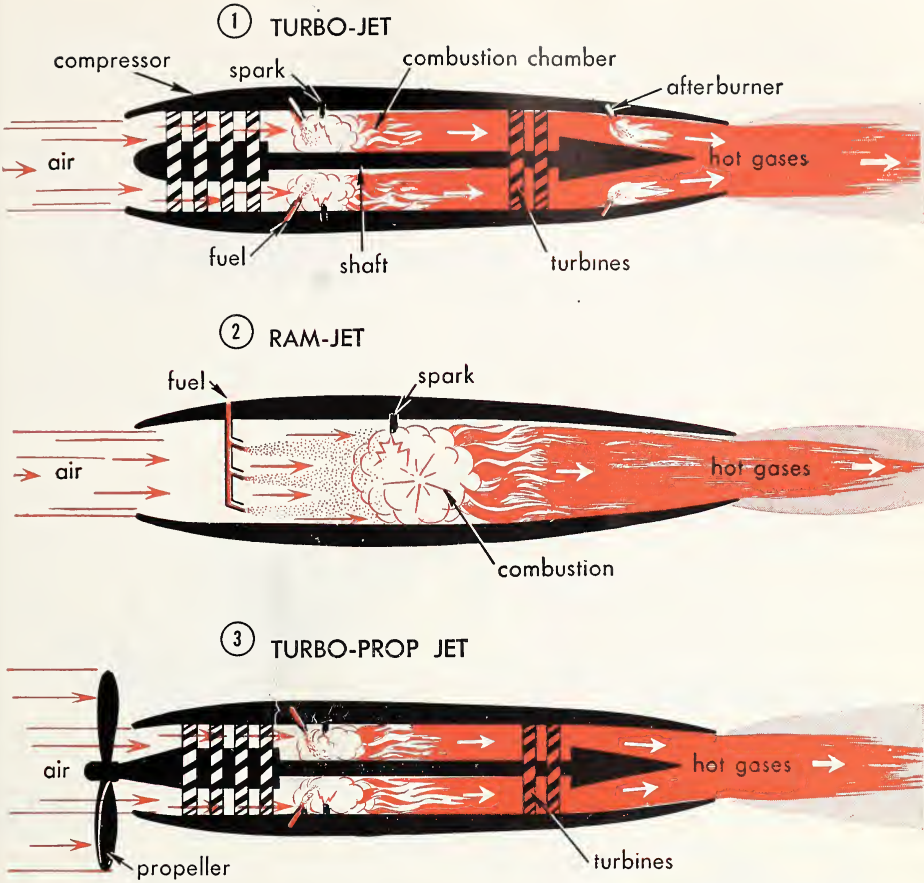
The ram-jet engine is the simplest form of a jet engine. It has no moving parts. It takes air into the front opening and crowds it into a small space. The fuel is then sprayed in and burned. The hot gases shoot out the rear. In order to get enough air into the front opening, this engine must be moving through the air at a high speed before it will start to work. Therefore, airplanes that use the ram-jet engine must have some other kind of power to take off from the ground.

The Turbo-Prop Engine

The turbo-prop engine is much like the turbo-jet engine, except that it has a propeller. This propeller is turned by the same shaft that turns the compressor and gas turbine. Though smaller and lighter in weight, the turbo-prop engine gives more power than do heavier and larger piston engines. It uses less fuel than the turbo-jet engine or ram-jet engine.

Now return to Fig. 286 and study the differences among the three engines.

[1] A fourth, less common type of jet engine is the *pulse-jet* engine.



286 *1, the turbo-jet engine.* The fuel is shot into the combustion chamber, compressed with air by a compressor, and exploded. *2, the ram-jet engine.* How is the air compressed in this engine? *3, the turbo-prop engine.* How is this engine different from a turbo-jet engine?

SPEED OF AIRPLANES

Since the Wright brothers' first flight, the speed of airplanes with propellers has risen from 31 miles an hour to over 600 miles an hour. There is a limit, however, to the speed that propellers can pull an airplane through the air. Beyond 600 miles an hour the propeller blades whirl so fast that the air they push back over the plane's wings is too rough to give the plane the needed lift (Fig. 286). It is clear that, for greater speed, another kind of engine is needed than one that turns a propeller.

The push of air against an airplane becomes greater as the speed of the plane increases. At 760 miles an hour

the push of the air is so great that it seems to place a wall, or barrier, against any faster speed. Scientists call this wall the "sound barrier."

The Sound Barrier

"Sound" is made when some fast-moving or vibrating object hits air. This makes waves in air, somewhat the same way a stone you throw into water makes waves on the surface. Waves in water move in only one direction — outward. Sound waves in air move in all directions — upward, downward, and sideways. When these waves hit your ear, you "hear" sound.

The speed of sound is the speed with which these waves move through the air. This speed, at sea level, is about 760 miles an hour. Above the earth, where the air is thinner and cooler, sound waves do not travel quite so fast.

If an airplane flies 300 miles an hour, the sound waves it sends out travel away from the plane much faster than the plane flies. But if the plane travels 760 miles an hour, it catches up with its speeding sound waves and piles them up in front of the plane. At the same time the front edges of the airplane also pile up air. All this mass of squeezed-together, piled-up air, pushed along at 760 miles an hour, then becomes one huge *shock wave*. Shock waves, the main part of the sound barrier, can rip the wings from an ordinary airplane. To lessen the effect of these shock waves on planes as they fly through the sound barrier, planes have been given a different-shaped wing (Fig. 287).

Planes also have been given turbojet and rocket engines for greater speed. Although rocket engines use up their fuel in a few minutes, in this short time they can give the plane a speed many times the speed of sound.

Smashing the Sound Barrier

What does it feel like to smash the sound barrier? Here is a first-hand report by Gene May, the second man to fly faster than sound.

I took off without rockets, saving precious fuel for my test. At a high altitude I leveled off. On the ground, radar stations stood by to track the plane through its run. They radioed me they were ready.

I was ready, too.

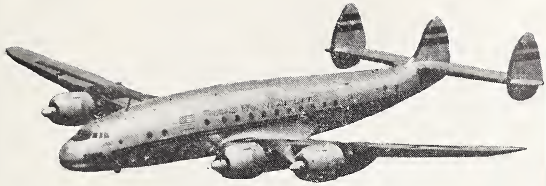
I backed off some twenty miles and started in. I got every last ounce of stuff from the jet, and that was a lot of speed. Then I cut in number one rocket. I felt a walloping pickup. My air-speed indicator took a big jump toward 760 miles an hour. I was already knocking on the wall. Suddenly I decided to get it over with, and kicked in the other three rockets all at once.

The increase in speed hit so hard it flattened me against the back of my seat. Suddenly the ship rolled to the left. I got it back. Suddenly it rolled to the right. I got it back again. She started to climb. Again I got the ship under control. Now she flew perfectly. That was all the shock there was. After that the flying was glassy smooth, quite the smoothest flying I had ever known . . . .

Soon the rockets spent their fuel. Now I was going more slowly, going back down through the barrier of sound. I felt again the rolling of the airplane, first one way and then the other. Gradually, the ship became easier to control, and I was back in the world I had left a scant three minutes before . . . .[1]

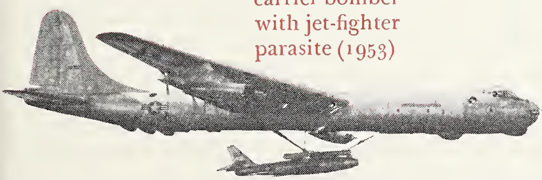
On December 12, 1953, Major Charles Yeager flew the X-IA, a

[1] From "My Biggest Thrill," *Flying* Magazine, June, 1953.



trans-oceanic
passenger plane (1944)

vertical-take-off
jet fighter (1953)



carrier bomber
with jet-fighter
parasite (1953)

military biplane
(1917)

seaplane (1929)

dirigible (1935)

four-place
personal plane
(1948)

jet bomber (1958)

287 The story of flight in pictures. *Project:* Make a scrapbook to picture other changes that have taken place in aircraft design since the first aircraft was launched.

rocket plane, 1,650 miles an hour, or over twice the speed of sound. Do you really have any idea how fast this is? Not many people do. But you can get some idea if you have ever fired a .22 caliber rifle, which is a rifle used for target practice and hunting small game. The .22 rifle shoots a bullet that goes 1,300 feet per second. You will certainly agree that if a man went through the air at that speed, he would be going very fast indeed. When Major Yeager flew his X-1A plane 1,650 miles per hour, *his speed was almost twice the speed of a .22 rifle bullet!*

Is there any limit to the speed of airplanes? Let us look at the facts. If an airplane flew for just five minutes at a speed of 2,600 miles an hour, 40,000 feet above the earth, air friction would heat its metal surface to a temperature of 900° F., even though the air itself is icy cold — some 65° below zero at this altitude. Unless they were protected, persons inside the plane would be killed by the heat. At faster speeds the metal of the plane would light up as a meteor does when it flashes across the sky. Scientists are studying new materials to pass this heat barrier, just as they earlier passed the sound barrier.

At today's speeds, most airplanes need large airfields with miles of runway to land on. However, there is one kind of plane that needs a space only a little larger than itself for landing or taking off. This plane is the helicopter, or planes that work on the principle of the helicopter.

The Helicopter

Pilots sometimes call a helicopter an egg beater. Do you see why? Its "wings" — really large, long propeller blades — are whirled by an engine and can be tilted in many directions (p. 502). By tilting the wings, the helicopter may be flown up or down, forward or backward, and sideways. It can also stay still in the air over one spot. Think what this means in rescuing persons who have survived shipwreck or plane crashes! Hundreds of persons have been saved by helicopters.

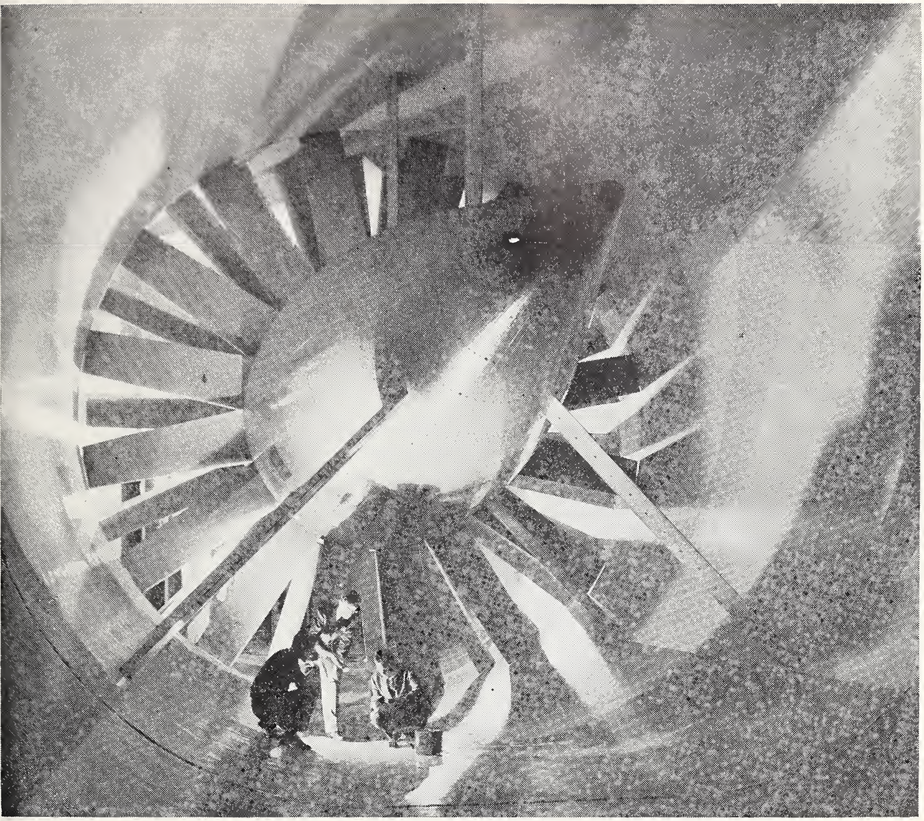
The large whirling blades on a helicopter cause a twisting motion that would make the helicopter useless for flying if it were not for a small propeller on the tail that pushes against this motion (p. 502). Large helicopters, with two sets of wing blades whirling in opposite directions, stop this twisting motion and can lift heavy loads from places where no other airplane can take off or land.

Helicopters are now used to carry passengers short distances to places within 50 to 100 miles from airports. Large, fixed-wing planes lose money on such trips, but airline companies can make a profit by using helicopters.

A Look into the Future

It is now a matter of only a few flying hours to cross oceans. Today airplanes carry millions of passengers and hundreds of thousands of tons of freight in the United States each year. Some freight and passenger planes weigh over 100 tons and can carry 20 tons of cargo. Planes weighing much more than this, powered by jet engines, are now being built. Airports are also being built or lengthened or strengthened everywhere for these sky monsters.

Science has also made better controls for safety. No longer does a



BOEING AIRPLANE CO.

288 This powerful electric fan can send air at a speed of hundreds of miles per hour against scale models of airplanes hung in the wind tunnel. Does this picture help you understand how engineers work to find out what shape the wing of an airplane must have to fly faster than the speed of sound?

plane have to fly "blind" in a fog or storm. The pilot has radar pictures of the sky ahead and the ground below. He can see his landing field. He also has a radio "beam" to guide him in landing, and he can talk by radio to the control tower on the field. It is as safe today to travel by air as to travel by automobile, railroad, or steamship.

The changes in the last few years have been so many that no one can really say what the next few years will bring to travel on land, on sea, or in the air. Plans have been drawn up for atomic engines for airplanes that use only 1 pound of uranium 235 to give the power of 1,700,000 pounds of gasoline. One of these engines is being built right now. Atomic engines like those in the submarines *Nautilus* and *Sea Wolf* may also be used in ocean liners to give them greater speed while saving the space now used for carrying fuel oil. It is safe to say that changes in travel will be exciting.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

Archimedes' principle	ailerons	lift
clutch	fuselage	thrust
transmission	jet engine	rudder
Kingston valves	helicopter	stabilizer
vent valves	drag	

1. gears used to make an automobile go forward or backward
2. the forward motion given to an airplane by a propeller or jet engine
3. a movable part of an airplane that can cause the plane to go right or left
4. a force which lessens the forward motion or speed of a plane
5. any object placed in a liquid is pushed upward by a force equal to the weight of the liquid displaced by the object
6. a device that connects or disconnects the power of the engine from the rear wheels of an automobile
7. valves in a submarine that when opened let water fill the ballast tanks
8. the main body of an airplane, which holds the passengers
9. a device on the tail of an airplane to balance the plane
10. air pressure under the wing of the plane
11. flaps set in the edge of airplane wings to control the course of the plane
12. valves that let air out of the ballast tanks in a submarine
13. an engine that uses the thrust of hot gases for power
14. an airplane that can stay still in the air over one spot

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. A . . . disconnects the power of an automobile engine from the rear wheels.
2. The . . . of an automobile can make it go forward or backward.
3. Any substance floats in water when it displaces the amount of water . . . to its own weight.
4. Water pressure . . . with depth.
5. Banking of an airplane is done by moving the . . . .
6. The . . . of an airplane contains passengers and freight.
7. An airplane's nose is made to rise or fall by using the . . . .
8. An airplane gets lift when the pressure on the upper surface of the wing is . . . than the pressure on the lower surface.

9. The angle of the wing as it meets air resistance is called the angle of . . . .

10. A speed of 760 miles per hour at sea level is the speed of . . . .

11. Streamlining of planes has greatly lessened . . . .

12. Engines that depend on the thrust of hot gases for power are called . . . engines.

13. A plane which can rise or descend vertically and travel in any direction is called a . . . .

GOING FURTHER

1. *Driving and automobile safety.* Because most boys and girls of your age will sometime drive an automobile, appoint committees in your science class to do the following:

a. Have the chairman of one committee write to two or three automobile makers for booklets about their automobiles. Ask for information and pictures of engines, clutches, transmission and differential gears, and any other literature they can send. Have the committee report on this information.

b. Have the chairman of one committee make arrangements for the committee to visit the manager of an automobile repair and service station. If possible, have the manager explain to the students what problems he has to solve in making repairs and giving service to customers. Ask the members of this committee to give a report of their visit.

c. Ask the chairman of one committee to write to your state registry of motor vehicles for a booklet telling about rules for safe driving. Have members of the committee report on these rules and show by diagrams on the blackboard what the rules mean.

d. Have the chairman of one committee invite the chief of police or another police officer to speak to the class about safe driving. Next day, let each member of this committee tell the class *his* idea of safe driving.

2. *Checking Archimedes' principle.* Tie a piece of string around a stone or a small piece of scrap iron. Weigh the stone or iron with a spring balance. Fill a jar or beaker brimful of water. Now weigh on the balance any small pail into which the bottom of the beaker will fit. Place the jar of water in the pail. With the stone attached by string to the balance, slowly lower the stone into the water. Note the difference between the weight of the stone in air and its weight in water. How much weight did the stone seem to lose?

Remove the jar from the pail that now holds the overflowed water. Weigh the pail again and make note of its increased weight. What is the weight of the overflowed water? Compare this weight with the loss of weight of the iron or the stone in water. Is Archimedes' principle true?

3. *An experiment in "floating."* Fill a pail with water. Place a slightly weighted empty tin can on the surface of the water in the pail. Does it sink? Now add more weight to the tin can by dropping in pebbles or sand. Note how the can sinks as its weight increases. Does it displace more and more water?

Remove the tin can, empty it, and smash it flat with a hammer, bending it

over and over again. Place the battered can in the water. Does it sink? Does it displace as much water as before? What effects have size and weight in making objects sink or float?

4. *Checking Bernoulli's principle.* Make a fold in a sheet of composition paper about 1 inch from the end. Hold the fold about 2 inches away from your mouth, and blow against the fold and over the top of the remaining paper. What do you conclude as to the reason for the lift given to the paper? Is Bernoulli's principle true?

5. Make a trip to a nearby airport. Write down all the parts of an airplane you can identify.

Put on Your Thinking Cap

1. In what ways have the automobile and truck affected life in the United States?

2. If you were to give a talk on the need of a safety program, what points of careful driving would you stress?

3. In what ways has the T form of rails affected the growth of railroads?

4. Why does a ship made of steel float, whereas a piece of steel sinks in water?

5. A pine log is pushed into a river. The log contains 4 cubic feet and weighs 125 pounds. Will it sink or float? (Remember that a cubic foot of water weighs 62.5 pounds.)

6. How does an airplane get lift?

7. If the drag of an airplane is less than its thrust, can the airplane fly? Why?

Adding to Your Library

We suggest the following books and pamphlets for your reading. You will find each one exciting.

1. *Automotive Encyclopedia*, 3rd edition, The Goodheart-Willcox Co., 1322 S. Wabash Ave., Chicago, 1958. A complete course in automobile mechanics with special emphasis on fundamental principles and trouble shooting.

2. *O.K. for Drive-Away* by Henry B. Lent, Macmillan, 1951. This book explains how automobiles are built and how clutch and transmission gears work to transfer the power from the engine to the wheels.

3. *Sportsmanlike Driving*, 3rd edition, American Automobile Association, Mills Building, Washington, D.C., 1955. This book is a *must* for you to read. There are many diagrams and pictures to show you how to drive an automobile.

4. *MG Guide* by John Christy and Karl Ludvigsen, Sports Car Press, Ltd., 1958. Performance modifications for sports cars.

5. *Treasury of Foreign Cars, Old and New* by Floyd Clymer, McGraw, 1957.

6. *From Kite to Kitty Hawk* by Richard W. Bishop, Crowell, 1958.

7. *Boy's Book of Flight* by David LeRoi, Iliffe and Sons, 1957.

8. *From the Ground Up* by A. F. (Sandy) MacDonald, Aviation Service Corporation. Problems a pilot should be able to tackle.

9. *The Helicopter* by Jacob Shapiro, Macmillan, 1958.

10. *Rockets and Missiles* by Erik Bergaust, Putnam, 1957. Up-to-date picture-caption story of America's rockets and missiles.

11. *The Wright Brothers* by Fred C. Kelly, rev. edition, Farrar, Strauss, 1951. This is the complete story, with photos, of how Orville and Wilbur Wright flew the first airplane.

12. *Fill 'Er Up* by Bellamy Partridge, McGraw, 1952. Here is the story of the first 50 years of making automobiles. The pictures are informative and interesting.

A Bit of Research

There is much more to learn about the automobile than you have learned from reading this chapter. We suggest that you find out about the following from the library, from automobile companies, or from your local garage:

1. How the electrical system works.

2. How the braking system works.

3. How the steering system works.

These are three of the most important systems, on which safe driving depends. In your science notebook make a drawing of the systems, showing the parts.

Careers for You

There are hundreds of careers that you may choose from in the making of automobiles, ships, and airplanes. There are hundreds of other careers waiting for your choice in servicing, selling, or designing automobiles; in work connected with large shipping lines, or on the ships themselves; in piloting and servicing airplanes, or in other work at airports or with airlines.

How can you get training for these careers? Most universities give training for *engineering* careers with automobile, ship, and airplane companies. There are many schools, some even in large airports, where men are trained to *service airplanes* and women are trained as *hostesses*. There are maritime academies in many seacoast cities where men are trained as *ship's officers* and *engineers*. If you really want a career in the field of transportation, the opportunity awaits you.

MODEL AIRPLANES AS A hobby

Have you ever seen a model airplane contest? If you have, you know what thrills and satisfaction boys and girls get from flying their own model planes. The ones who watch get a thrill, too, because some of these planes fly at a speed of over 100 miles an hour.

One great satisfaction a model plane builder gets is seeing a plane he has just built make its first successful flight. Perhaps, however, he has built a nonflying model. Then his thrill comes when he first puts the model on display as an exact copy of a large aircraft.

Today thousands of boys and girls enjoy the hobby of making model airplanes. Their enjoyment comes from building something with their own hands and brain, and from getting the results they planned for when they started their work. Perhaps you, too, want to build model airplanes as your hobby. If you do, you will find interesting reading and advice in this section.

WHAT YOU SHOULD HAVE TO START WORK

When you look at the sleek lines of a model airplane, you may feel that building a model plane is a big job. That is not true. The building of a model plane is made up of several little jobs. Each one of the little jobs

must be done just right to make the finished plane a fine piece of work. You need only four things:

1. A place to work.
2. Tools to work with.
3. Materials to work with.
4. A plan of the model plane you want to build.

A Place to Work

When you are building a model plane, you need a room you can use as a workshop. Ask your parents which room they will let you use. You will need good lighting and a place to store safely the materials you use. A table or small bench to work on is a must. Here you may check your plans as you work. A small box with a hinged lid and lock is a good place to store tools. Most of the tools you will use are sharp. Be sure to keep them out of reach of small children.

Tools to Work With

A beginner in building model airplanes needs very few tools. You should have a jackknife with two sharp blades and sharp points. You will find it your most important tool for cutting and trimming away extra wood. Razor blades make a very useful tool for the fine cutting you need to do. Be sure, however, that they are placed in a holder, which you can get at any hardware store.

You will need two pairs of pliers; one pair of small size, with a round nose, and the other pair somewhat larger, with a flat nose and a wire-cutting edge on the side. You will need these pliers to bend landing gears as well as tail skids and propeller shafts.

Because you will often be taking measurements you will need a yardstick, a rolled steel tape, or a carpenter's folding rule. Whatever measuring device you use, it should be at least 36 inches long.

One of your very useful tools will be a changeable-blade coping (KOHP-ing) saw. You will use it to cut out parts from sheets of wood. Solid fuselage blanks are also cut to shape with this tool.

A small hand plane, as well as a hand drill and several sizes of twist drills, will be useful. The most used sizes of these drills are 1/32 inch, 1/16 inch, 3/32 inch, and 1/4 inch. You will also need a screw driver, a pair of scissors, and a tack hammer. Finally, for smoothing parts of your model, you will need sandpaper.

Materials to Work With

All flying model airplanes are made of balsa wood. This wood is very light and is easy to work. It must be handled carefully, however, because it is so soft that it can be dented with the thumbnail. Balsa wood can be bought in any store that sells model airplane materials. It comes in sticks of many widths and thicknesses or as "sheet balsa" in the form of thin boards that can be cut into strips or panels.

Bamboo is a hard, light wood that you can get in split lengths from model supply stores. It is stronger than balsa. When small strips are gently heated, they can be bent to form parts of a model plane that need strong support.

You can buy nails (1/4- and 3/8-inch sizes), small screws (1/4-inch size), wire, and similar materials at any hardware store. Pieces of aluminum, if you need them, are sold at model-

plane supply stores. There you may also buy the cement known as Ambroid Liquid Cement. Model plane makers agree that this is the best cement for such work.

Usually the covering of a flying model plane is a very fine grade of Japanese paper. Pure Para rubber strands or tiny gasoline engines power the flying models.

Plans of Model Planes

Every builder of a model plane carefully checks each step of his work with a plan of the plane he is building. Usually these plans are full-sized working drawings that the model builder has made himself or has enlarged from smaller drawings of planes he has found in books or model-airplane magazines. However, if the parts of the model plane have been bought in kit form, full-sized working drawings usually come with the kit. The advantage of using full-sized working drawings is that the size and shape of many parts of the plane can be drawn directly on sheet balsa wood and then cut out.

There are plans or working drawings for every model airplane. Which set of plans will you choose to use?

KINDS OF MODEL PLANES

As we said at the beginning of this hobby section, there are two kinds of model planes: nonflying and flying. The nonflying type is usually a solid model; that is, it is carved from solid pieces of balsa wood or white pine. There are, however, two main types of flying models: free-flight and control-line flight.

Nonflying Models

Nonflying model planes are built to be exact copies of large aircraft. When hung by small threads in a display cabinet or placed on a mantel, shelf, or desk, they seem to be really flying or about to rise from the ground. Solid models are useful also for wind-tunnel testing by airplane companies; for checking plane handling when designing aircraft carriers; and for laying out airfields and designing hangars.

Solid models are usually built to the scale of ¼ or ½ inch to the foot. That is, each ¼ or ½ inch of length or span on the model plane equals a foot on the full-size plane. When these models are used for display purposes, extra pains are taken to give them a smooth coat of paint and to include all the fittings possible. The solid model is perhaps the easiest one to build (Fig. 289).

Free-Flight Flying Models

Free flight means that once the model plane gets into the air, it is not controlled by anyone. The moment these planes take off, they are "on their own," and they must be perfectly balanced in order to stay in the air.

The simplest free-flight model you can build is a glider. The wings may have a span of 1 to 2 feet and are cut from solid sheet balsa. To lessen air resistance, the wings are carefully sanded and polished. Often these gliders take several minutes to return to the earth after being thrown into the air (Fig. 289).

After making a glider, you should build a rubber-powered model plane. It is much like the glider. It is called

a stick model because its fuselage is just big enough to hold the rubber strands that give it power. Stick model planes can fly several minutes if the rubber strands are wound up tightly enough (Fig. 289).

When you get further experience, you may want to build engine-powered, free-flying models. However, these models need much more care in building and often "crack up" in flying because their flight cannot be controlled. Perhaps the most popular are the control-line models.

Control-Line Flying Models

Control-line flying models are seen at every flying model airplane contest. Two wires from 25 to 100 feet long run from the plane to a vertical handle held in the flyer's hand. A helper starts the engine of the plane. The plane then takes off from the ground and flies around the flyer, who turns as the plane circles around him. By moving the vertical handle in his hand, the flier moves the elevators of the plane up or down, causing the plane to climb or dive.

Control-line planes are not hard to build; in fact, many beginners have built and flown them successfully. These models can be built with solid-sheet balsa wings and hollowed-out fuselages, thus giving them strength and protection against crack-ups (Fig. 289). You will have a lot of fun flying a control-line model plane.

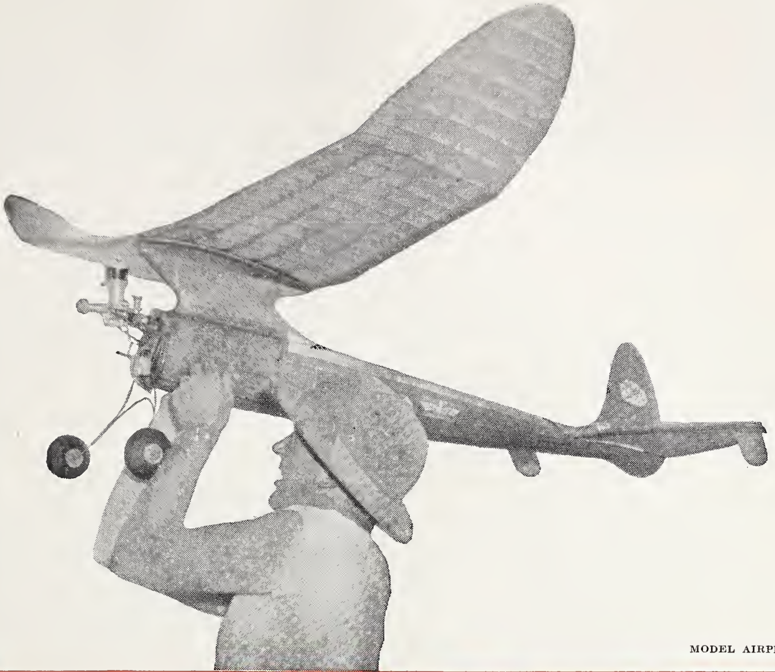
Will Model Airplanes Be Your Hobby?

In this hobby section there has not been room enough to tell of the many different kinds and types of model planes you can build. Only a few have been mentioned. However, in the reading list at the end of this section you can find complete instructions and plans for building many more. Will building model airplanes be your hobby?

Reading for the Model Plane Builder

These books are for boys (and girls) who are beginners and advanced beginners in building model planes. The last two tell you about building other things.

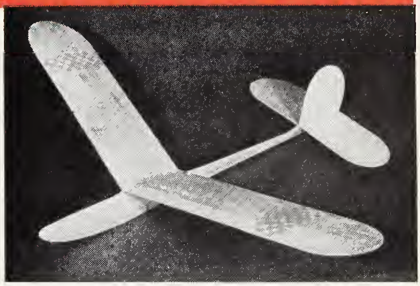
1. *The Model Plane Manual* by Walter A. Musciano, Herman, New York, 1953. You will find in this manual a list of the tools and materials a model plane builder needs. The author also tells how to build many free-flight and control-line planes.
2. *Building and Flying Scale Model Aircraft* by Walter A. Musciano, Herman, New York, 1953. The directions for building planes mentioned in this book are clear and simple. The beginner will find many of these planes easy to build.
3. *Model Jets and Rockets for Boys* by Raymond F. Yates, Harper, 1952. The first part of this book deals with the history and development of jets and rockets. If you would like to build model planes powered with jet and rocket engines, you will find several good plans and sets of directions in Chapters 3, 4, and 5.
4. *Build-It-Yourself Book for Boys* by the Editors of Popular Mechanics Press, 1956.



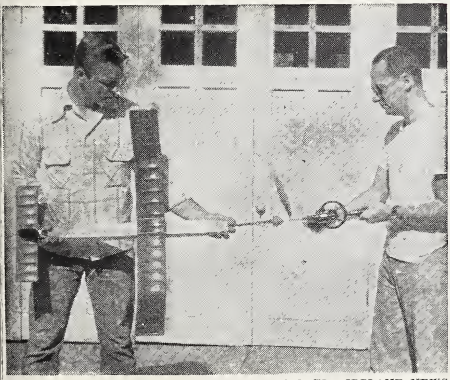
MODEL AIRPLANE NEWS

MODEL BUILDING

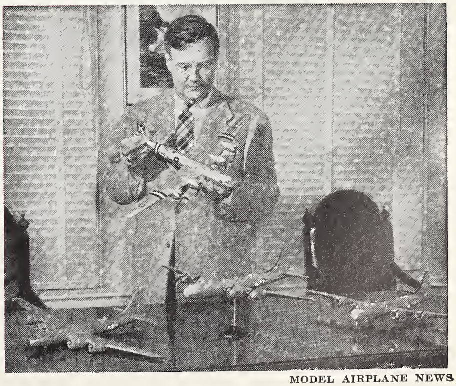
289 *Right*, a model glider. *Bottom right*, four solid scale-model airplanes, exact copies of a B–29. *Bottom left*, flying model powered by rubber bands. *Top*, gasoline-powered free-flight model. All are fun to build, and the powered models exciting to fly.



MUSCIANO FROM THE MODEL PLANE MANUAL



MODEL AIRPLANE NEWS



MODEL AIRPLANE NEWS

UNIT 8

Speeding Communication

Have you ever stopped to think of the many ways sound and light are used to communicate information? A siren may sound the passing of an ambulance. A searchlight may signal a plane to a safe night landing. Flares may warn of danger on the highway or drums announce an approaching parade. All these communicate as surely as spoken words. In this unit communication is about gathering and passing on information by using waves — light and sound waves and the range of electromagnetic waves.

We gather sound chiefly through the ears and light through the eyes. But if we had to rely on these organs alone, our information would be very limited. Scientists reasoned that light and sound were a form of energy and therefore could be harnessed. So scientists invented machines to bring us information with the speed of light. Better yet, they found ways of storing this information so that it would not be lost. You know many of these inventions — the telephone, the radio, television, cameras, the phonograph, radar, motion pictures. But how do they work? That is the story of this unit.

Your Science Inventory

How much do you already know about speeding communication? Copy the following questions and write your best answers. Check your answers when you finish reading this unit.

1 If you hear thunder four seconds after you see lightning, the storm is at a distance of about (a) 1,000 feet, (b) 2,000 feet, (c) 4,500 teet, (d) 6,000 feet.

2 A distant sound reaches the hearer most quickly through (a) air, (b) metal, (c) wood, (d) water.

3 If you stretch a rubber band and flick it with your finger, it will give off sound waves. Of the following statements, the one that is true is: (a) The more the band is stretched, the higher the note, (b) The more the band is stretched, the lower the note, (c) Stretching the band has no effect upon the sound, (d) The sound cannot be heard.

4 The hammer is a bone in the (a) foot, (b) shoulder, (c) jaw, (d) ear.

5 Bats and modern submarines detect obstacles by (a) echoes, (b) mirrors, (c) telescopic eyes, (d) deep sounds.

6 To make a periscope, a person needs (a) one mirror, (b) two mirrors, (c) three mirrors, (d) four mirrors.

7 The eyeballs of a nearsighted person are (a) longer than normal, (b) shorter than normal, (c) wider than normal, (d) normal in shape.

8 The lens in the eye is (a) concave, (b) convex, (c) concave-convex, (d) flat.

9 If rays of white light are passed through a prism, the rays next to the red rays in the visible spectrum will be (a) blue, (b) orange, (c) violet, (d) yellow.

10 Of these waves the ones that always travel at the same speed are (a) light waves, (b) sound waves, (c) water waves, (d) waves in a rope.

11 10^5 represents (a) 50, (b) 500, (c) 10,000, (d) 100,000.

12 X rays are most easily stopped by (a) bone, (b) lead, (c) water, (d) wood.

13 The waves that make it possible to photograph a hot object in a dark room are (a) hertzian waves, (b) infrared waves, (c) red waves, (d) ultraviolet waves.

14 An electron gun is (a) a cathode-ray tube, (b) an anode-ray tube, (c) a condenser, (d) a weapon.

15 Radar sets send out signals at the speed of (a) light, (b) sound, (c) 10,000 miles an hour, (d) a rifle bullet.

CHAPTER 26

Sound and Hearing

Plug your ears with cotton. Then put your hands over your ears — just for a minute or so. A different world without sound! Much of the world comes to you through your ears. Your ears are precious to you.

A MINER was sitting in a Washington, D.C., motion picture theater one snowy day. In spite of his interest in the film, he suddenly jumped out of his seat, shouting a warning of danger, and ran for the nearest exit. Moments later the roof caved in, killing some people and injuring others in the audience who had not heeded his warning.

Good hearing and good listening had saved the miner's life and the lives of others. A miner is by habit always alert for the sound of a possible cave-in, a constant danger in mines. His ear had caught the faint noises which had come just before the roof caved in because of the weight of the snow that had fallen on it. His mind had understood their meaning. Few people make such good use of their ears.

YOUR HEARING

Probably no two people hear the same things the same way, but every normal person has the same kind of organ to hear with, the human ear.

Collecting Sounds

The human ear has many parts, only one of which can be seen easily. This part is the outer ear. Each of your outer ears leads to a middle ear, which in turn connects with an inner ear (Fig. 290).

Hearing begins when sound *vibrations* reach your outer funnel-shaped ears.

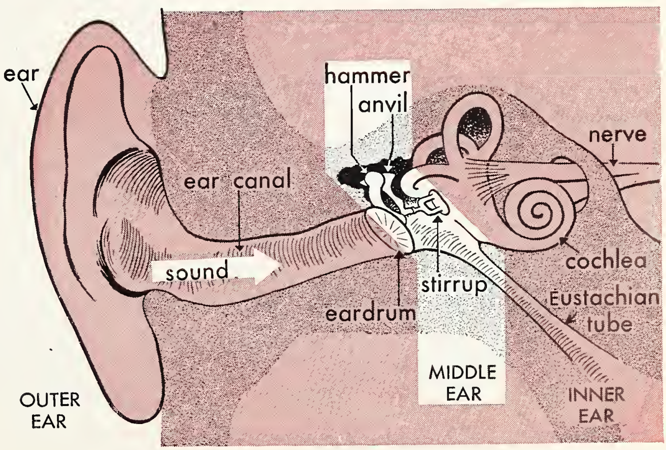
What are vibrations? Here is a way you can see as well as hear sound vibrations.

Stretch a rubber band as far as it will go and flick it with the nail of a finger. Notice how the rubber band moves back and forth; that is, it vibrates. If it vibrates too slowly you will hear no sound. Make it vibrate so fast that your eye cannot see more than a blur. Now you can hear a twanging sound. This sound is caused by the rapid motion or vibrations of the rubber band. These vibrations set up sound waves in the air, and some of them in turn set the air inside your ear in motion.

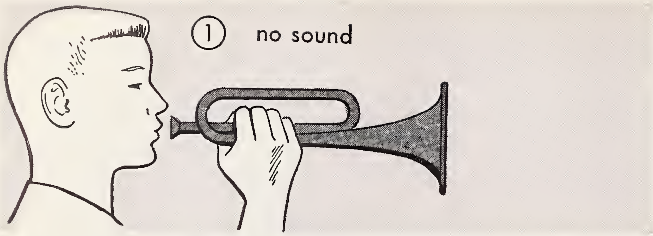
When a person plays the violin, he makes a few strings vibrate. These make sound waves that travel to your ear. A trumpet player makes sound waves by blowing air into his instrument. A drummer makes sound waves by causing the tight skin of his drum to vibrate. The air then carries these sound waves to your ears.

Things that are vibrating fast enough to make sounds that you can hear are usually moving back and forth so rapidly that you cannot see the vibrations. For instance, if you were to strike a tuning fork, you might hear the sound but you probably would not see the motion of the prongs of the fork except as a blur.

One way to see that a tuning fork makes vibrations is to strike it, then dip it quickly into a glass of water. The vibrations will make the water splash. Another way is to attach a needle to one of the prongs of the tuning fork before you strike it. Then while the fork is sounding, hold the point of the needle over a piece of glass that has been smoked in a candle flame. The needle will make true wavelike marks which you can easily see. A third way to show vibrations is to fasten a tiny mirror to a violin string. Shine the light from a flashlight against the mirror



290 The three main parts of the human ear. What is the purpose of each part?



291 When the bugle is blown, vibrations within it set in motion sound waves which spread out in all directions.

while someone else runs the violin bow across the string to make it vibrate. See how the beam of light reflected by the mirror dances on the opposite wall.

Listening with Your Brain

Vibrations carried by the air first reach your outer ear. They keep on traveling until they reach your *eardrum*. Then, if your eardrum is in good working order, it too begins to vibrate. The eardrum is a thin, skin-like tissue separating the outer ear from the middle ear.

When the eardrum starts to vibrate, it sets in motion the three smallest bones of the human body. They are called the hammer, the anvil, and the stirrup. Do not be fooled by the size of these bones as they appear in Fig. 290. Actually, they are about the size of the capital letters on this page.

When these three tiny bones move, they set up vibrations in a fluid in the inner ear. This fluid fills a remarkable snail-like coil in your inner ear. It is called the *cochlea* (KOK-lee-uh). In the cochlea are fibers placed in a way that may remind you of the strings of a harp or piano. These fibers come together to form a nerve which reaches to the brain. Thus the stimuli of sound reach your brain. Your brain enables you to recognize certain sounds as words, music, or noise. You listen with your ears and brain.

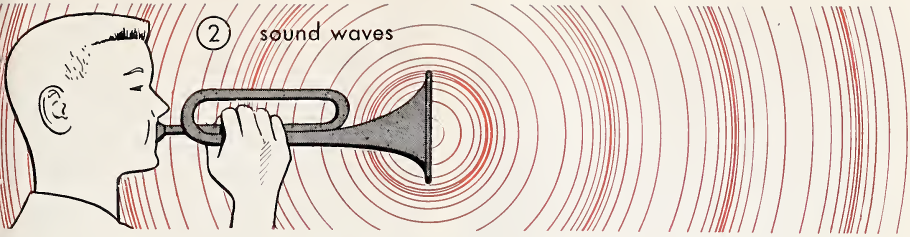
Why Some People Find It Hard to Hear

Some people are born deaf, and some become deaf later on. Deafness that comes after birth may be caused by an obstruction in the ear, or it may be the result of an injury. The injury may be an accident such as a broken eardrum, or it may be the aftereffect of an illness. Since the eardrum is so thin, it is easily damaged. It is not wise to use any hard object such as a toothpick or match to remove wax or dirt from your ears. Only soft, moist cotton should be used. If the wax is hard, let a doctor remove it. He knows how to do it without putting a hole through your eardrum. Sometimes the nerve connecting the cochlea to the brain is damaged, or the blood vessels leading to it may not be in working order.

You can easily find out how much less you can hear if there is something in your outer ear. First measure the distance at which you can no longer hear the ticking of a clock or watch. Then plug up your ears with soft wads of cotton and measure the distance again. It is much less, isn't it?

If you are left to take care of a small child, do not let him put things such as beans or beads into his ears. If you swim under water or dive, water may collect in your ears. You may get most of it out by bending

over.



over. Never neglect an injury to your ear. Go to your doctor, for he knows how to protect you against loss of hearing.

Discomfort in the Middle Ear

There are times when putting something into your ears makes sense. For instance, a plug of soft cotton in your ear when you are high diving or swimming under water may save you from a broken eardrum. A broken eardrum is real discomfort.

A change of air pressure against your eardrums may cause you mild discomfort for a few moments. You have had the feeling if you have ridden through a deep tunnel or traveled up or down in a high-speed elevator in a very tall building or blown your nose too hard. Do not let this kind of discomfort in your ears worry you. It usually goes away if you swallow a few times.

Swallowing causes the *Eustachian* (yoo-STAY-kee-un) *tubes* to open. These are air tubes leading from the back of the throat to an opening into the middle ear. Swallowing forces the air in the tubes up against the eardrums from the inside. This makes the pressure the same inside and outside the eardrum. It is the uneven pressure that causes your discomfort. During a bombardment soldiers are told to keep their mouths open to prevent broken eardrums which may be caused by the great, sudden blasts of pressure from the explosions. If the mouth is open, the air pressure changes in the Eustachian tubes at the same time that it changes in the outer ears.

Although the Eustachian tubes serve us well in one way, they are also paths along which germs may travel from the nose and throat into the middle ear. When this happens, you may have an earache. If you should have an earache, go to the doctor at once and follow his advice. If infection of the middle ear is not corrected, it may lead to the loss of hearing. Resolve now not to do anything to cause a loss in your hearing.

Vibrations and Waves

We know that vibrating objects produce sounds. Really, it is more correct to say that vibrating objects produce sound waves. Each vibration produces one sound wave. You are familiar with water waves. You have probably tossed a stone into a pond and watched the ripples or waves spread out from the center. How are sound waves different from water waves? First, you can see water waves but not sound waves. Second, sound waves move in all directions from the point where the sound begins. They do this in a way that is unlike a water wave but easy to show.

To show the way a sound wave moves along, the pupils in your class may place themselves, one behind the other, two feet apart in a long line. At a signal, the last pupil steps forward just far enough to push the pupil ahead of him a bit. Then he steps back to his first position. As each pupil is touched, he moves forward, pushes a bit, and steps back. This is the way a sound wave moves.

Really, it is the molecules of the gases in the air which move back and forth. Imagine that each pupil is a molecule. Each molecule moves forward when pushed until it pushes against another molecule. Now this molecule in its turn pushes against another. Once each molecule has pushed against its neighbor, it returns as the pupils did. Sound waves are a series of forward and backward movements of the molecules in the air.

Sound Vibrations You Cannot Hear

Strangely enough, we cannot hear all sounds. Scientists have found that an object must vibrate at least 16 times per second to make sound waves which we can hear. They have also found that we cannot hear sounds made by vibrations of more than 20,000 per second. With special instruments, scientists have been able to measure and photograph sounds lower and higher than the human ear can hear.

It may surprise you to learn that bats make sounds with their mouths when they fly. This is their way of avoiding whatever is in the path of their flight. The bat sends out the sound and listens for an echo. Hearing none, he knows his path is clear. Hearing one, he swerves.

If you could catch a bat and tape its mouth shut, you would see how much it depends upon the sounds it makes. These sounds are too high for us to hear. Such gagged bats in flight crash into objects and often are killed. Scientists call sounds beyond the range of our hearing *ultrasonic* (ul-truh-SON-ik) *sounds*. Bats, insects, and other animals have been using ultrasonic sounds for thousands of years. Man is just beginning to make use of sounds he cannot hear.

Ultrasonic Sonar

The science of ultrasonics is very young. It was used in World War II to locate submarines under the sea. Enemy submarines had been escaping by stopping their engines when our destroyers were near. When they lay quietly under water, they could not be found by ordinary sound detectors. To find these submarines, our navy put *sonar* (SOH-nahr) to work.

"Sonar" stands for *so*und *n*avigation *a*nd *r*anging apparatus. Sonar can find objects that are beyond the range of ordinary sighting and hearing devices. Sonar sends out sound waves which bounce back when they strike an object such as a submarine. Just as flying bats detect the presence of objects by their ultrasonic sounds, so sonar detects objects which can be identified by the pattern of the echo they send back.

Echoes

Sonar works because sound waves can bounce. You can make ordinary sounds bounce too. You call them echoes. Have you ever noticed how

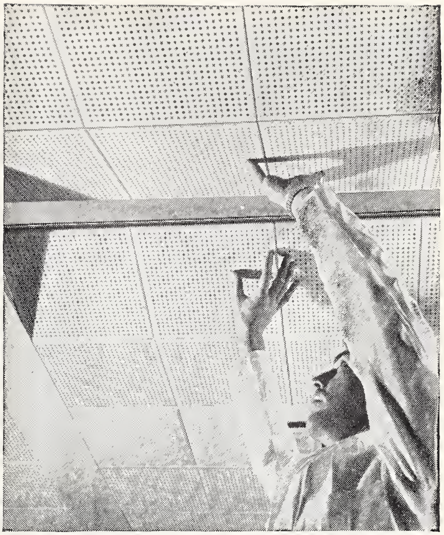
difficult it is to hear what is being said in some auditoriums, busy restaurants, and even some classrooms? Blame the echoes. When walls and ceilings reflect sound waves, the jumble of echoes makes a horrible din.

Echo Killing

No doubt the best way to fight echoes is to call in an *acoustics* (uh-KOO-stiks) expert. Acoustics is the science of sound. An acoustics expert is an echo killer. When he kills unwanted sounds in an auditorium, a restaurant, or a broadcasting studio, he does it by catching the sound waves before they can become echoes.

One trick of an acoustics expert is to hang soft draperies on walls and window frames. These materials absorb the sound waves. You may have noticed that your voice seems louder when carpets have been taken out of a room and curtains are down. Take out the furniture, and the sound seems still louder. The clothing and bodies of people in a room also absorb sound waves. Thus the voices of actors rehearsing a play in an empty auditorium may sound louder than when there is an audience present.

Here is another trick of the acoustics expert. He covers the walls and ceilings or both with a layer of material that is full of holes or pores. These openings break up the sound waves so that very little of the wave can echo back into your ears to annoy you (Fig. 292). You can test what these materials do by sitting for a time in a noisy room without such insulation. Then sit in a room that has acoustical materials on the ceiling or walls. You will find the insulated room is more restful. It is



CELOTEX CORP.

292 The holes in this ceiling material absorb the sounds by breaking up the waves that echo and re-echo from smooth surfaces.

easier to work in it because most of the echoes have been stopped.

How Do Sounds Travel?

There is one place where you would not be bothered by echoes, or for that matter by any sounds. You may have guessed from your earlier reading that this place might be the moon. The moon has no air to carry sounds. Thus it is a place where there can be no echoes.

Air is not the only substance that can carry sound waves. You have already seen (p. 536) how the bones of your head carry sound vibrations. Put your ear against the top of your desk while someone else touches a vibrating tuning fork to a distant corner of that desk. You will hear the tone of the fork even more clearly than you did when it was held in the air near your ear. What would you

TABLE 14 Speed of Sound

(Speeds are at about 20° C., or normal room temperature)

	Feet per Second
In Solids	
Iron	16,820
Copper	11,670
Pine wood	10,900
Silver	8,550
In Liquids	
Water	4,800
Alcohol	3,890
In Gases	
Air (20° C.)	1,130
Air (0° C.)	1,090

From this table, which of these is the best carrier of sound — air, water, wood, or metal?

conclude? You would be right if you said that some solids carry sound waves better than the air does. Metals, for example, are very good carriers of sound. Can liquids such as water also carry sound?

To test whether water can carry sound, put one ear below the surface of the pond or lake the next time you go swimming. Ask someone to strike two stones together under the water. You will find that water carries sound very well. It does it better than air.

Test explosions made underwater have been picked up by instruments as far away as 3,000 miles. Table 14 shows you how fast sound travels through some common substances.

Sounds and Storms

You can use the following facts about sounds to find out how far away a thunderstorm is. You know that there are lightning flashes during a thunderstorm and that the sound of thunder always comes after the lightning. Sometimes the storm is so far away that you cannot hear the thunder. Sometimes you hear the thunder several seconds after you see the lightning. The length of time between the flash and the sound shows you about how far away the storm is. You can see the lightning almost at once because light travels about 186,000 miles per second. But the sound of thunder travels much more slowly, at about 1,100 feet per second.

Let us suppose you see the lightning. At the same instant you look at your watch. Five seconds later you hear thunder. How far away was the lightning? Since sound travels through the air at about 1,100 feet per second, in 5 seconds it went $5 \times 1,100$, or 5,500 feet (a little over a mile, which is 5,280 feet).

In the same way, soldiers can guess at the range of an enemy gun. They note the length of time between seeing the flash of the gun and hearing the roar of the gun's explosion. By doing the same thing you can guess at how far away not-too-distant fireworks are. If you have seen the newsreel pictures of the atomic bomb tests, you may remember that there was some time between the flash of the explosion and its roar. This proves that the person who was taking the pictures was a long distance from the exploding bomb. If he had not been, he probably would not have lived to bring back the pictures.

From experiments you have read and done, you now know the facts about sound which are given in the box on the next page. Remember that both light and sound are "waves," but are very different in speed.

VIBRATIONS YOU MAKE

Man not only hears certain sounds; he makes them. The ability to produce sounds made it possible for man to develop language, one of his most powerful tools. Read the last sentence aloud. How did you make the sounds which were the words?

Your Voice ✓

Of course you made those sounds with your voice. Therefore, there must be something in your throat that vibrates rapidly enough to produce the sounds. Human sounds are made in the voice box, also called the *larynx* (LAIR-inks). If you could look into your larynx, you would find your vocal cords; they look like flat folds or bands (Fig. 293). Put your hand lightly on the larynx just below your Adam's apple. Read the words in the next sentence aloud. Can you feel the vibrations of your vocal cords?

The vibrations are made when the air in your lungs rushes past the vocal

The Nature of Sound

1. Sounds travel in waves.

2. Vibrations produce sound waves.

3. Our ears can hear sounds made by objects vibrating between 16 times and 20,000 times per second.

4. We cannot hear some sounds.

5. Sounds which bounce back, or are reflected back, are called echoes.

6. Ultrasonic waves cause vibrations which cannot be heard by the human ear.

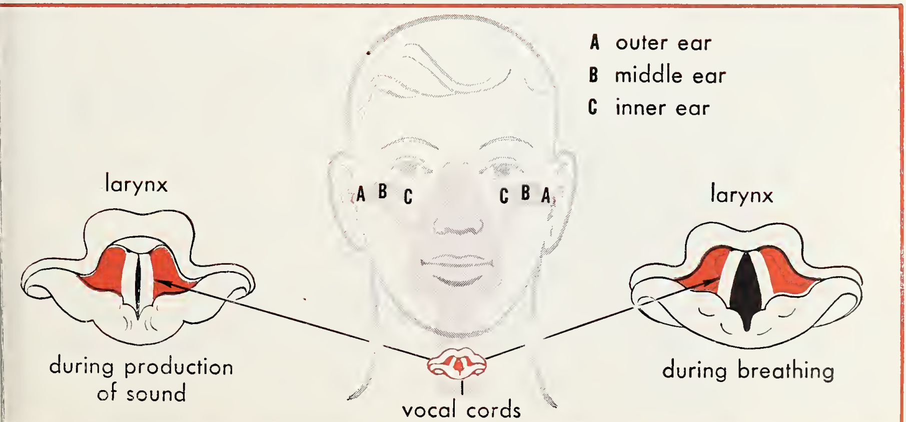
7. Ultrasonics can be put to good use, as in the detection of submarines.

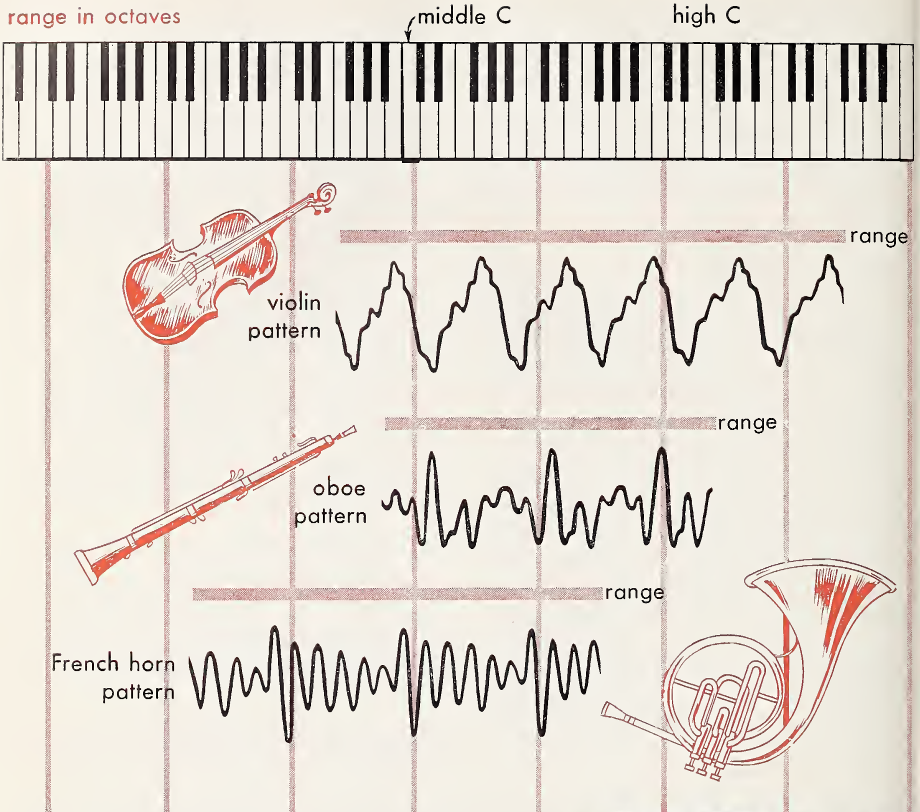
8. Acoustics is the science of sound.

9. Unwanted echoes can be killed by various sound-insulating materials.

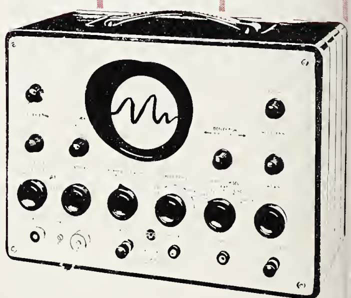
10. Sounds travel at different speeds through different substances.

293 To speak pleasantly you must really use your head. Your brain controls what you say. Your voice is produced by the vocal cords. Air from your lungs forced through the cords causes them to vibrate, producing sound. The air passages and bones in your skull add resonance. What happens to the vocal cords during breathing?





294 Musical sounds are produced by vibrations whose waves form regular patterns. These patterns may be seen with the aid of an oscilloscope (*lower right*). Compare the patterns of the violin, oboe, and French horn. The heavy horizontal lines show the range of these instruments, and the keyboard allows you to compare them with the range of a piano. How many full octaves has a standard piano?



cords. In ordinary breathing your vocal cords are wide apart (Fig. 293). In speaking and singing, the cords are close together and air is forced across them, causing them to vibrate.

How Sounds Differ

If all voices sounded alike, this would be an uninteresting and confusing world. Fortunately, sounds may differ in several ways. The ways

sounds differ may be seen most clearly when they are fed into a microphone which is connected to an *oscilloscope* (os-SIL-oh-skohp). This instrument (Fig. 294) shows the pattern of sound waves as curves of light on a screen.

Suppose you were to sing *do re me fa sol la ti do* into the microphone of an oscilloscope. The waves which are caused by the sound *do* would have a certain wave pattern. If you kept singing *do* for a few moments without changing your voice in any way, you would find that all the waves one after another would look exactly alike. If you could count them, you would find that there were a certain number per second. For instance, the key of middle C on the piano sets in motion 256 sound waves per second. The number of sound waves per second is called the *frequency*, and this number tells us the *pitch* of a sound. We say that frequency determines the pitch. Let us look into the meaning of pitch and see how it depends on the frequency.

Sing the musical scale again, beginning at middle C. What is the difference between the first and the last *do?* You know that you sing up the scale to reach the second *do*. It is of a higher pitch than the first *do*. If you could see the waves of the higher *do*, you would count more of them per second. The frequency of the higher *do* is greater and its pitch is higher. In other words, the more vibrations per second a sound has, the higher the pitch. The fewer the vibrations a sound has, the lower the frequency and the lower the pitch. A soprano, for instance, sings at a higher frequency (more vibrations per second) than does a deep bass. Deep voices have lower frequencies (fewer vibrations) than do high voices. The higher the pitch, the higher the voice; the lower the pitch, the lower the voice.

Pitch and Loudness

Do not confuse pitch and loudness. Pitch depends upon the frequency of the waves. If you were to sing *do* softly, you would see on the screen of the oscilloscope a wave that is short from top to bottom (Fig. 294). If you were to sing the same *do* loudly, the waves would be higher from top to bottom. The pitch would be the same, but the height of the waves would be greater. The height of a wave is called its *amplitude* (AM-plih-tyood). The greater the amplitude, the louder the sound you will hear. On the screen of the oscilloscope the wave of *do* sung softly will be a smaller wave from top to bottom than *do* of the same pitch sung loudly.

295 Students testing the tone of a home-made musical instrument. The pattern of the sound waves it makes will be shown on the oscilloscope. Sound waves look like the ones in Fig. 294.

UNESCO "COURIER"

Quality of Sounds

Voices can differ in quality as well as in loudness and pitch. Some voices are husky; others are brassy, harsh, or soft. Musical instruments, too, have different "voices." For instance, a flute and a French horn may be used to make sounds of the same pitch and loudness, but the sounds are different in quality. This is because the instruments are of a different size and shape. Human beings also differ in the size and shape of their vocal organs. Each person uses his mouth, tongue, teeth, and vocal cords a bit differently. So even if you and your friend sing a note of the same pitch and loudness, it may not sound the same. This is because voices also differ in *resonance* (REZ-uh-n'ns).

Resonance

To demonstrate resonance, strike a tuning fork and listen to it as you hold it in your hand. Now strike it again and put the end against a door or hollow box. The sound will appear fuller the second time. The extra fullness is caused by the added vibration of the thing you rested the tuning fork against. By using a delicate instrument, you would find that the whole door or box is vibrating with the tuning fork.

Have you ever noticed the way a violin is made? The box is made so that it vibrates when the bow plays across the strings. How much a violin is worth depends a great deal upon the resonance of its box. More than two centuries ago a man named Stradivarius (strad-ih-VAIR-ee-us) made violins in Italy. Today musicians prize his violins because of the wonderful resonance of the box.

What part of you gives resonance to your voice? The way to find out is to sing out a sound such as *ah* as long as you wish. While you are singing, pinch your nose gently so that the air passages are closed a bit. Do you notice any change in the sound? Besides the air passages in your nose, mouth, and throat, which you know about, there are the *sinuses* (SY-nuh-sez). These are small caves or tubes near your nose. Have you ever noticed how different your voice sounds when you have a cold? The sinuses may fill up with fluid and change the resonance of your voice.

Extending the Sound of Your Voice

In this chapter, you have learned how you hear sounds and how you make sounds. Using the voice is the most common way people communicate with one another. The better a person can use his voice to produce sounds, the better he can make himself heard over a distance. Some great speakers and singers can be heard clearly in a building as large as an opera house without having to use mechanical or electrical aid. But even such fine voices cannot reach very far. Today most speakers use a microphone if talking in a large or noisy room. The microphone is just one part of a public-address system that was unknown fifty years ago.

Many years earlier, man had found ways to send messages quickly over distances too great for his own voice to carry. He saw that light (and sight for receiving it) were more useful for sending a message quickly across many miles. In the next chapter, you will learn how man exchanges ideas by using the speed of light.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

vibrations	sonar	pitch
eardrum	acoustics	amplitude
cochlea	larynx	resonance
Eustachian tubes	oscilloscope	sinuses
ultrasonics	frequency	

1. the number of vibrations or waves per second
2. a part of the windpipe containing the vocal cords
3. the science of sounds pitched above the range of human hearing
4. a thin membrane in the ear which vibrates as sound waves strike it
5. a machine that changes sound waves into a wave that can be seen
6. the air tubes leading from the back of the mouth to the middle ears
7. the height of a sound wave
8. submarine detection and ranging apparatus using the echoes of ultrasonic sounds
9. a certain number of vibrations per second producing a distinct note or sound
10. the science dealing with sounds
11. the small canals which when filled with air add resonance to the human voice
12. the special quality of a sound caused by the vibration of nearby materials
13. a coiled part of the inner ear which helps the brain to distinguish different sounds
14. rapid forward and backward motions of sound waves

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. Sound waves are made by objects that are . . . .
2. The sounds made by some animals, like bats, cannot be heard by us because these sounds are . . . .
3. Sounds usually reach our ears as . . . which travel through the . . . .
4. Sounds may be distinguished by their differences in . . . , . . . , and . . . .
5. Upon reaching our ears, sound waves set in motion a membrane called the . . . .
6. The three bones of the middle ear are the . . . , . . . , and . . . .
7. The middle ear is connected to the mouth by the . . . tubes, which open when we . . . .
8. The human voice is caused by the vibration of the . . . .
9. The vibration of the air in our sinuses adds . . . to our voice.
10. Sound waves travel more rapidly in . . . and . . . than in air.

GOING FURTHER

In the Laboratory and Field

transfer

1. *Making a string telephone.* A string telephone is a simple device for sending a message a short distance. Punch a small hole in the center of the bottom of two cardboard cups of the kind used for ice cream or cottage cheese. Push the ends of a string or thread through these holes. Knot the ends so that the strings cannot pull out. Hold one cup to your mouth and talk while someone else holds the other cup to his ear. Be sure to hold the string stretched taut and do not let your fingers or anything else touch the string. Try different distances and see how far apart the cups can be and still work.

2. *Musical glasses.* Make a set of musical glasses or bottles. You will need at least eight of the same kind. Add different amounts of water to each bottle until you have them tuned to the scale of a piano. Then play a simple tune; use a spoon to strike the bottles or glasses.

Put on Your Thinking Cap

1. How far away is a cliff if a man can hear the echo of his shout two seconds after he utters it?

2. Why does an orchestra rehearsing in an empty auditorium sound louder than it does when an audience is present?

3. Why do voices sound different even though the words are the same.

A Bit of Research

How well does your sense of hearing serve you? With your teacher's help you can find out. Ask your teacher to prepare a set of twenty or more things that make noises which you should be able to recognize. At a signal you can be blindfolded, along with the rest of your class, which has been divided into two teams as if for a spelling bee. If you guess correctly what has made the noise, you remain in, but if you guess wrong the person opposite you has to name it. Only those who drop out may remove their blindfolds. This test will not tell you how well you hear but it will tell how well you have trained yourself to use your hearing.

Adding to Your Library

1. *Hearing Aids* by Matthew Mandl, Macmillan, 1953. All about use, care, and repair of hearing aids.

2. *Sound, an Experiment Book* by Marian E. Baer, Holiday, 1952.

3. *The Magic of Sound* by Larry Kettelkamp, Morrow, 1956.

Careers for You

Find out how much demand there is for people who know acoustics. If your guidance teacher cannot tell you about the opportunities in this field, write to the physics department of a large university. Persons trained in acoustics are needed as *architects*, as *sound engineers*, and as *designers* of sound effects in radio and television studios.

CHAPTER 27

Light and Sight

Close your eyes for one minute. How would it be if you could not see your way about? If you could not enjoy the world brought to you by your eyes? Close your eyes and think how important your eyes are.

HAVE YOU ever watched the referee at a football or basketball game signal to the scorekeeper what happened? He tells a great deal just by putting his hands on his hips or by holding his arms in a certain way. He is making signs that carry meaning to those who know the code he is using.

Early men, who could not understand each other's speech sounds, discovered that they could exchange ideas by using certain signs made with arms, hands, and fingers. The American Indians developed their sign language so well that they used it to carry on long conversations. Since they often wanted to leave a message somewhere along a wilderness trail, they also made marks on trees or piled up stones or twigs in certain ways.

You may think that sign language is no longer used, but even the letters on this page are a form of sign language. Look at them one by one. They are not pictures such as the Egyptians once used. They are signs that we have learned to put together in ways that have meaning for us even though they might have no

meaning for a person who does not know our language.

Besides these signs, which we call letters, there are many special signs such as the following:

π # \$ % & △ ϕ * ¶ + @ ¢ ♃ ! £

How many of them do you recognize? Some of them have meaning for you, and others may not. The point is, if you and someone else do not know the same code, you cannot exchange ideas. Therefore, part of your education is learning the signs that most people use.

Of course, you must see the signs before you can understand them. A glance that is too hasty or centered upon the wrong thing may give you a poor or a wrong idea. You must learn to be a good observer. This means that you must learn to note details accurately and as completely as possible. Some people fail to understand things because they are not trained to be good observers.

No matter how well you are able to observe, you will need enough light if you are to see the details. You cannot expect to read this page in the dark. Light is always needed when we want to gain ideas by using our eyesight. The question is, how much light do we need for different seeing tasks? Before we can find the answer to this question, we must know something about light itself.

LIGHT

In Chapter 26, you learned that you can tell how far away a storm is by counting the seconds between the flash of lightning and the sound of the thunder. The flash of light and the rumble of the thunder start coming toward you at about the same time. You see the light before you hear the sound because light waves travel so much faster than sound waves.

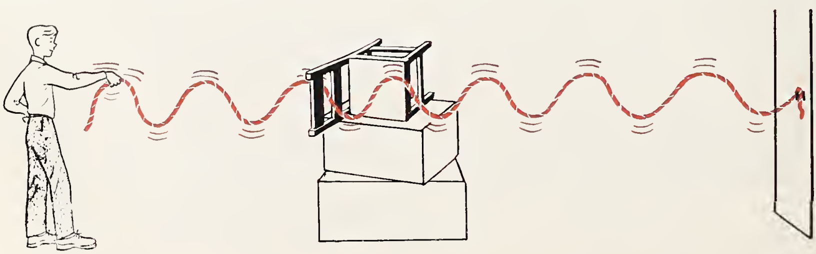
Speed of Light

In 1931, the American scientist Albert A. Michelson (MY-k'l-son) decided to find out exactly how fast light travels. Everyone knew that its speed was about 186,000 miles per second. But scientists like to measure things as exactly as possible. Michelson found that the true speed of light is 186,284 miles per second. Sound, as you remember, travels about 1,100 feet per second. Thus light travels about 900,000 times as fast as sound.

Light Waves

Light waves are like water waves in some ways, but light waves travel much faster and are much smaller. About 50,000 light waves take up no more than an inch of space. A light wave is thus $\frac{1}{50,000}$ of an inch.

296 Light waves, represented by rope waves in the diagram, travel freely if nothing interferes.



Light waves move in two directions at the same time, up and down and back and forth. It is hard to imagine how any wave could vibrate like this. You will understand this better if you will do this simple thing.

Tie one end of a rope to a fixed object such as a post (Fig. 296). With only a little practice you will be able to send a wave along the rope in either an up-and-down or sideways direction.

If you have a chair with slats at home, put one end of the rope through the slats (Fig. 296). When the slats are upright, you can wave the rope up and down but not sideways. Turn the chair the other way, and you can wave the rope sideways but not up and down. Now put two chairs back to back, one with the slats upright and the other with the slats sideways. Run the rope through the two chair backs. Why are you now unable to set up any waves in the rope?

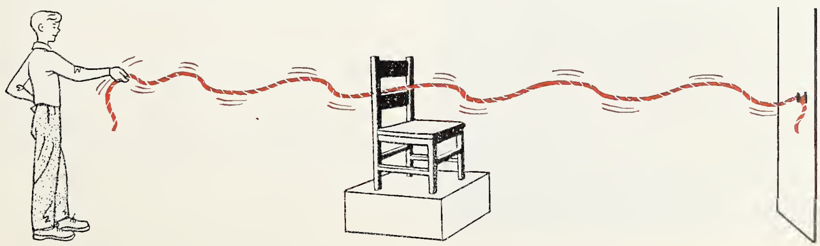
Certain types of 3-D moving pictures make use of the double vibrations of light waves. Two pictures are printed on the same film. *One* picture is made with a camera fitted with a special filter that admits only the light waves vibrating *sideways*. The other picture is made with a camera lens fitted with a filter that admits only the light waves that vibrate up and down. To view these pictures correctly you are given a pair of eyeglasses which are simply filters like the ones used on the cameras. They allow you to see only one picture with each eye. Since the pictures you see with each eye have been originally taken at slightly different angles, you get the effect of depth and roundness while viewing the picture as you would if you were seeing it with your own eyes. Of course, there are other ways to produce the same 3-D effects, but right now let us see where light rays come from.

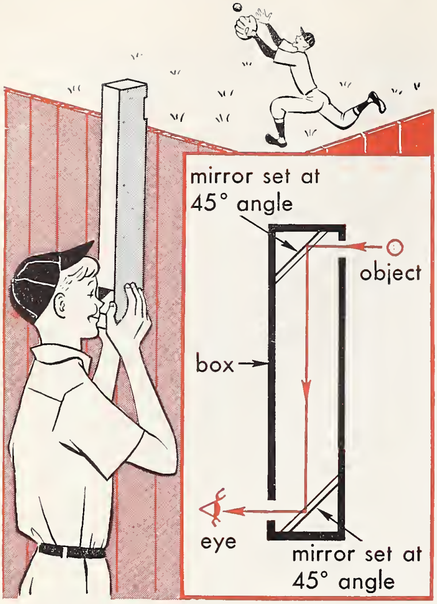
Sources of Light

Many things can act as the source of light waves. Examples are given in Table 15 on the next page. The most common source of light is some hot object such as the sun, an electric light bulb, or a fire.

What are some of the ways in which signals are made with light? No doubt you can think of many useful ways. The signal flares that are planted along a railroad track behind a stalled train tell just one idea, but it is a very important one. They tell the engineer of any train coming along to stop even though he cannot see the train that is halted. Lifeboats also have signal flares that can be shot

The chair slats are like a grating. They permit waves to move in only one direction. What would happen if two chairs were used at the same time in the positions shown? Try this yourself.





297 A periscope changes the direction of light by reflecting it twice, both times through an angle of 45 degrees. *Project:* Make a periscope like the one shown here.

up like skyrockets. They tell rescue crews where to look. Now go ahead. Make your own list of light sources that may be used for sending ideas.

How Light Travels

Before you study lighting, you should know how light travels.

Try looking through a piece of rubber tubing that is about 18 inches long. See if you can make the light from a candle travel through the tube to your eye. Do you see the light? Keep trying until you do see it. Then look at the position of the tubing. You will find that you can see the light source only when the tube is perfectly straight. You may now conclude that light waves travel in straight lines. In other words, light cannot travel around a corner, and you cannot see around a corner unless something is used to make the light change its direction.

TABLE 15 Producing Light Energy

Things to Do	*Energy Change Produced*
1 Mix solution A * and solution B † by pouring them at the same time into a gallon jug half full of water. Do this in the dark.	1 Chemical energy has produced radiant (light) energy.
2 Heat a piece of magnesium ribbon in a Bunsen flame.	2 Chemical energy has produced radiant energy.
3 Turn on an electric light bulb.	3 Electrical energy has produced radiant energy.
4 Operate a friction gas lighter, a cigarette lighter without fuel, or a toy sparkler.	4 Mechanical energy has produced radiant energy.
5 Heat an iron nail until it glows cherry red.	5 Heat energy has produced radiant energy.

* Solution A: ¼ teaspoon lye dissolved in 1 pint of water. Add to this a piece of luminol the size of a cherry pit. Dissolve thoroughly. Take care not to spill the solution on your clothing. Wash with water if you do so.

† Solution B: ½ teaspoon potassium ferricyanide dissolved in ½ pint of water plus ½ pint hydrogen peroxide of the type which can be bought in a drugstore.

A periscope (Fig. 297) is one of the things that change the direction of light waves so that you can see around a corner. As a matter of fact, you are able to see most things only because they send to your eyes light that has reached them from some source. To put it another way, we see things because they are properly lighted.

LIGHTING

When light rays strike any object, they bounce off again. That is to say, they are *reflected* from the object. When this happens, the object is lighted by reflected light.

Quality of Lighting

There are two main types of reflecting surfaces, shiny and dull. A mirror is a shiny surface; it gives direct reflection. Mirrors of various kinds have been used for thousands of years for sending signals with light. The soldiers of ancient Greece used their polished shields as mirrors to send battle messages to watchmen on distant hills.

A simple periscope is a tube with a mirror at each end set at a 45-degree angle (Fig. 297). By using a periscope a watcher can see what is going on without being seen. So you see that mirrrors may be used for receiving as well as for sending information.

If sunlight from a mirror shines in your eyes, you know it is blinding. To see things with comfort, we want the light to come to our eyes in a less direct way. The surfaces of most of the things we look at are dull. They are dull because they are not polished. Even a surface like your skin, which does not feel rough, is rough compared to a mirror. From a dull surface the light reflected is scattered, or *diffused*. Because diffused light is scattered in many directions, it is easy to look at anything which has a dull surface.

Even a dull surface may reflect unwanted light into your eyes. This unwanted light is called *glare*. When you are reading or writing, you can avoid glare by placing your work so that light shines on it properly. Seat yourself in different positions as you read this book and note in which position there is the least glare. If you are right-handed, we think you will find the most comfort when you read or write if the light comes over your left shoulder. Try out different combinations of light position, posture, and work position until you find the one that seems best for you. Compare your arrangement with that of the student in Fig. 298.

298 *Top*, proper lighting of a student's desk. *Bottom*, the student has made his seeing task difficult. His work area is too bright, and the room too dark.

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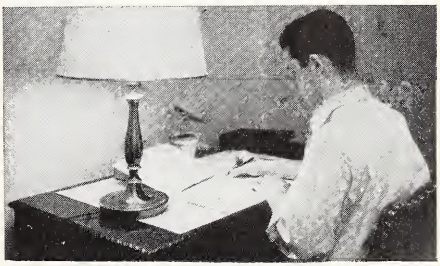

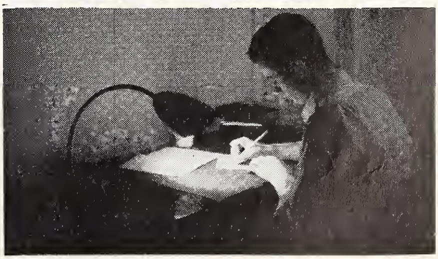

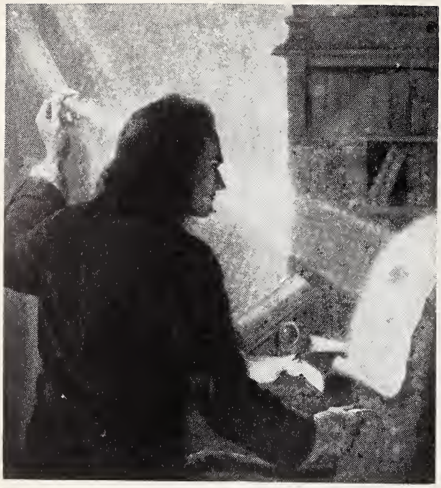

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299 Sir Isaac Newton produced a visible band of colors (a spectrum) by letting a ray of sunlight pass through a three-sided glass prism. Note how it spreads and bends the ray.

Breaking up White Light

Up to now, we have been talking about light as if it were all one color — white. From your daily experience, you know that there are many different colors. How are they made?

Our explanation begins with an experiment done by the famous English scientist, Sir Isaac Newton, at Trinity College in 1666. You can repeat the main part of this experiment simply by holding a three-sided glass prism in a ray of light (Fig. 299).

Newton, by doing this, found that a ray of white light is not just one kind of light. It is really made up of different kinds of light waves, six of which can be clearly seen by your eye as different colors. Each of these colors has a different wave length. Again remember that light travels in a straight line. When light enters a glass prism, the direction of the wave is changed and the light ray is bent. Each wave length is bent differently. Thus the colors which are mixed together in white light are separated by the prism. The series of colors which appears is called a *spectrum.* In a spectrum the light waves are arranged from the shortest (violet) to the longest (red). Light waves which make red are bent the least by a glass prism. Slightly shorter waves make orange; then come yellow, green, blue, and violet. The waves that make violet are the shortest in the visible spectrum, that is, in the spectrum we can see.

We speak of the visible spectrum to distinguish it from the invisible rays which are also a part of the spectrum of white light. Among the invisible rays are infrared (longer than red) and ultraviolet (shorter than violet). These rays are also found in sunlight. We will discuss these longer and shorter rays in Chapter 29.

The color of something seen by reflected light depends in part upon the kind of light rays it reflects. A piece of red cloth looks red because it reflects more waves of red than of any other color. You see red because most of the other color waves are absorbed by the cloth. A green blotter pad looks green because it reflects green light waves and absorbs all the other colors. A sheet of white paper reflects nearly all the light rays. Thus it appears to have the color of white when white light is shining on it and red if only red light is shining on it. On the other hand, a sheet of black paper absorbs nearly all the rays of light. Black is not a color but the absence of color. Grays are made by mixing black and white. Have you ever noticed how many shades of gray there are? How can you account for this?

Rules for Good Lighting

1. Judge a lamp by the way its light is directed rather than by its brightness.

2. Is the light steady or flickering? The light should be steady, and the task should also be held steady.

3. Avoid glare caused by unshaded lamps and by the reflection of light directly into the eyes.

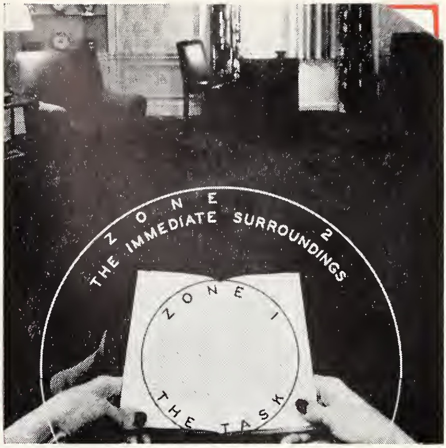
4. Use light where it is needed most, but also have enough general lighting so that the zones around your seeing task are neither too bright nor too dark.

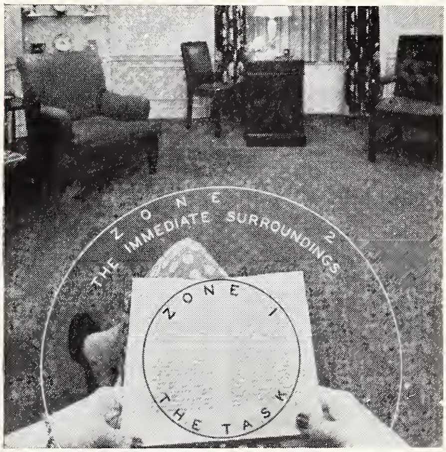
5. Light for reading and writing should come over one side or shoulder. In this position your head and hands will not cast shadows over your book or paper; glare will be reduced.

6. Examine your light fixtures and lamps. Dirt should be cleaned from bulbs, globes, and reflectors. Any blackened electric light bulbs should be replaced.

Comfortable Seeing Conditions

Seeing comfort depends in part upon the amount of light on the work surface. It also depends upon the brightness of the zone around your seeing task. Figure 300 shows you the three zones that affect your seeing comfort when you are reading a book. If you have no light in the room except the one that is lighting your book, zones 2 and 3 may be so far below zone 1 in their brightness that you will feel tired or uncomfortable within a short time. If you try to read while facing a much brighter zone, you will also be displeased. Zone 3 should not be more than 10 times as bright as nor less than $\frac{1}{10}$ the brightness of zone 1. Zone 2 should be about the same brightness as zone 1.





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300 Lighting the area around a seeing task is just as important as lighting the task itself. *Above*, zone 2 and the zone beyond (zone 3) are too dark. *Below*, proper lighting of all zones reduces eyestrain.

How to Get Proper Home Lighting

Proper lighting can be judged best by the beauty and comfort of the surroundings. If the room is full of heavy, ugly shadows, or if the people in it suffer from headaches and eyestrain (Fig. 300), the room is not properly lighted. You can use the

general rules shown in the box as a guide to judging your home lighting.

These are good rules to follow if you want your eyes to do their best work in comfort. You will understand the importance of eye comfort all the more after you learn how your eyes use light for seeing.

SEEING

Sight is light plus the help of the eye and the brain. Our eyes are truly our windows to the world. They are so wonderful and precious that everyone should know their structure and use.

An eye contains the parts for seeing: the eyeball, the socket in which the eyeball moves, and the muscles and nerves that move the eyeball. Since the eye is a living part of the body, it has in it the means of staying alive and useful. It has blood vessels to bring food and remove cell wastes, an eyelid and lashes to protect it, and tear glands to wash away dust and to lubricate it. Then there are the parts that make it possible for us to see. Do you know what they are?

From Light to Sight

Let us follow a ray of light as it reflects from this page and enters your eye. First, the ray, along with many others just like it, goes through a transparent shield called the *cornea* (KOR-nee-uh) (Fig. 301). A material is transparent if you can see through it. The surface of the cornea is kept clean by the regular blinking of your eyelid. The cleaning fluid is supplied by your tear glands.

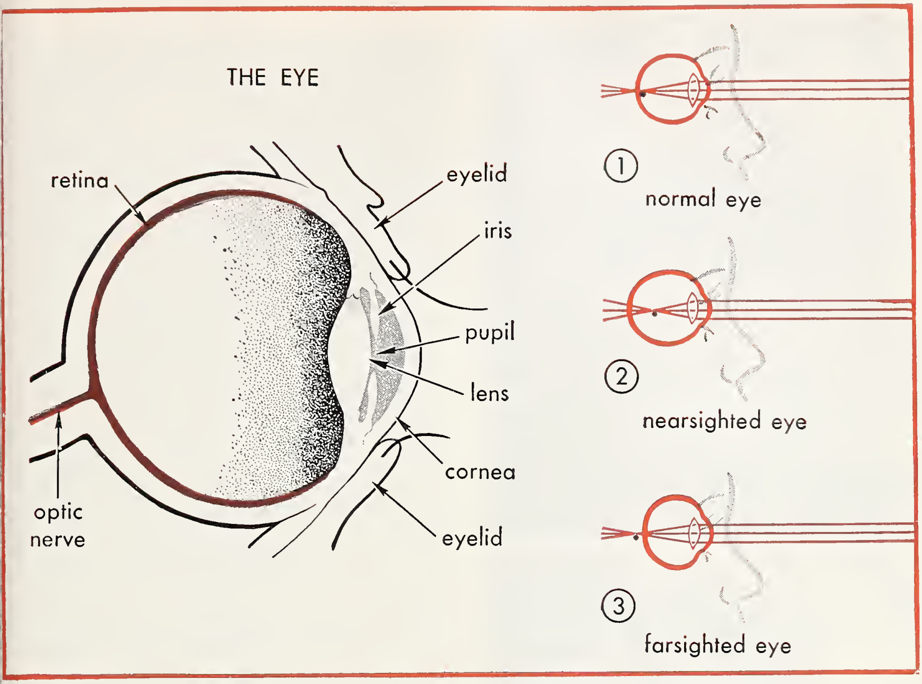
From the cornea, the ray goes through an opening in your eyeball called the *pupil*. The pupil is a hole in a doughnut-shaped screen of muscle tissue called the *iris* (EYE-riss). The iris is usually blue, brown, gray, or some shade of these colors.

Look at your own pupils in a mirror. Are they large or small? Make the room as dark as possible. Wait a minute. Then turn on a dim light and again look at your eyes. The pupils will be larger. The muscle in the iris makes the pupil smaller in bright light and larger in darkness. Thus your eyes are protected from light that is too strong.

The light ray passing through the pupil enters the *lens* of your eye. The lens focuses the light ray upon the *retina* (RET-ih-nuh). The retina is made up of a great number of cells that are sensitive to light. These cells have two shapes which look something like rods and cones. These cells are sensitive not just to light but to the different wave lengths of light. Thus they permit us to see things in their proper colors. Nerves join all these cells of the retina to a large nerve, the *optic nerve* which enters your brain. It is your brain that interprets the meaning of the things you see. We see with our brain as well as with our eyes.

Some Common Defects of the Eye

If the eye sees poorly, the brain may give you an incorrect idea. Often the mistakes you make are caused by poor eyesight which plays tricks upon your brain. The eye is such a delicate organ that a number of things may go wrong with it. As soon as you know something is wrong with your eyes, you should go to an eye doctor for



301 Light rays enter the human eye through the opening in the iris called the pupil. Then, if the eye is normal (*1*), the lens focuses the rays on the retina. If the eye is nearsighted (*2*) or farsighted (*3*), the rays are not focused sharply on the retina.

advice. If you neglect eye trouble, it may get worse. What are some of the things that can go wrong with your eyes?

An eyelash or a large speck of dust may fall upon your cornea and get under your eyelid. This is a minor trouble, but it can cause you a good deal of annoyance. Do not try to remove it with a sharp or pointed instrument or fingernail, and do not rub your eye. The speck can usually be removed by another person with a bit of moist cotton. If the object is stuck to or embedded in the lid or cornea, a doctor should remove it.

More serious are the faults that cause poor vision. What are they? It should be clear that a defect in any one of the several parts of the eye may cause faulty vision. For proper vision, the rays of light must be brought to a sharp focus upon the retina. An eye may have several defects at the same time which may balance each other to some extent or simply make double trouble. Here, as we mention each defect, we will assume it is the only defect and that the other parts of the eye are perfect.

One cause of faulty vision may be an eyeball of the wrong length from front to back. If the eyeball is too long, the image will be focused in front of the retina and, of course, will be indistinct. Such a person is *near-*

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302 *Top to bottom*, to a nearsighted passenger in the back seat the boy seems indistinct, the driver clear; to a farsighted passenger, the boy seems clear, the driver less clear; to a passenger with astigmatism, the whole scene is indistinct; but to a passenger with normal or corrected vision, the whole scene is clear.

sighted because only objects held near his eyes can be focused clearly (Figs. 301 and 302).

On the other hand, if a person's eyeball is not long enough, the image will be focused behind the retina. Then the person is *farsighted* because only objects held far from his eyes can be focused clearly.

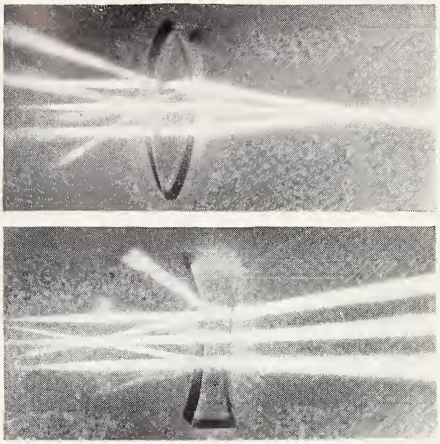
If you have normal vision, you may find it hard to understand what the correct focusing of light rays has to do with good vision. But take a hand lens and hold it too close to your eyes, and you will see how your normally clear vision becomes indistinct. Just as you spoiled your good vision with a lens, you can correct poor vision with a lens. Your lens muscles can change the shape of the lens in your eye only a bit. Beyond that, in order to correct a defect, you must wear eyeglasses, which are lenses designed by a doctor. Many cases of poor vision are caused not by eyeballs of the wrong length but by lenses of the wrong kind. The eyeglasses your friend is wearing may help you to see better if you borrow them, but they will probably make your vision worse. Eyeglasses must be made to order for you. To understand this, you will need to know how lenses bend rays of light.

How Lenses Bend Light Rays

When you did Newton's spectrum experiment (p. 552), you saw how a glass prism bends light rays. Notice what happens when you place two glass prisms base to base and shoot a beam of light through them. The rays bend so that they come together a short distance beyond the prisms. This point where the rays meet is called the *focus.*

Now replace the two prisms with one piece of glass curved so that it is thickest at its middle. If we pass several rays of light through it, as in Fig. 303, we see they are brought to a focus. This kind of lens is called a *convex* (KON-veks) *lens*. It makes light rays come together, or converge. The point at which they come together is the focus of the lens.

Suppose you turn the two prisms so that they now rest edge to edge. Notice that the light rays are now spread apart as they go through the glass. A lens of similar shape (wide at the edges and narrow in the middle) will also spread light rays (Fig. 303). This type of lens is called a *concave* (kon-KAYV) *lens*. Its sides look hollow like caves.



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303 Light rays coming from the left are brought together by the convex lens (*top*) and spread apart by the concave lens (*bottom*). The extra rays are caused by reflections from the lens surface. *Project:* If you have lenses, note how they change any object you examine.

How Lenses Correct Vision

The lens of your eye is a convex lens. It is elastic. This means that it can change its shape slightly and become more convex or less convex, but it cannot become concave. In this way, you can focus sharply upon things that are a few inches away from your eye and on things that are miles away. Try focusing your glance on objects at different distances. You will notice that you can change your focus instantly. The lens in your eye changes quickly (a doctor would say it *accommodates*) to allow you to see things both near and far.

Wonderful as they are, especially when you are young, the lenses of your eyes cannot change enough to overcome extreme faults in your vision. Therefore, we must aid them by wearing eyeglasses of the right kind. What kind is the right kind? Only a doctor can tell exactly, because fitting glasses requires training.

You will remember that a farsighted person's eyeball is not long enough (Figs. 301 and 302). We can bring the rays of light to a focus on his retina by moving the point of focus nearer to the lens (that is, toward the front of the eyeball). He needs a convex lens in his eyeglasses.

What about the nearsighted person? His eyeball is too long. We must move the focal point away from the lens (back to the retina). This can be done by spreading the light rays a bit with a concave lens. If you would like to see the effects of these lenses upon your own vision, borrow eyeglasses from your friends. Are the lenses convex or concave?

You may have seen older people who need two pairs of eyeglasses, one for reading and close work and one for distance. Or they may wear *bifocal* (by-FOH-k'l) eyeglasses combin-

Good Conditions for Reading

1. Do you sit straight while reading?
2. Do you have enough light to give you good seeing conditions?
3. Does the light come from the right direction?
4. If you wear eyeglasses, are they of the right kind? Do you keep them clean?
5. Do you have your eyes examined regularly?

ing two lenses in one piece of glass. These people need two lenses because their own lenses have lost their *elasticity* (ee-las-TISS-ih-tee). Their lenses are no longer able to accommodate well enough to allow them to see clearly objects both far and near. Ask a person who wears bifocals to show you his eyeglasses and compare them with ordinary eyeglasses.

How Well Do You Use Your Eyes?

Have you had your eyes tested lately? The most common test uses the Snellen Eye Charts with letters of different sizes. The test may show that you have normal vision, but this does not necessarily mean that you use your eyes well.

There is only a certain amount of help that other people can give you. After that you are on your own.

Have you ever gone on a field trip with a trained woodsman? Have you noticed how he sees animals and plants, tracks and signs that you have missed? You may wonder how he does it, and yet his eyesight may be no better than yours. The difference is that he has trained himself to use his eyesight to see things that other people overlook. One way to increase your ability to see things is to let your glance linger longer on things. Another trick is to think about what you see. Notice small details. Thus you become not only a person who sees but one who observes.

A scientist must be a good observer. He must be able to describe what he sees. This means being able to put into words a description of what he has seen. To observe means to see well but also to attach meaning to what you see. How accurate an observer are you?

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

reflected light	retina	convex lens
spectrum	optic nerve	concave lens
cornea	farsighted	accommodation
pupil	nearsighted	
iris	focus	

1. the path by which light rays seen by the eye are carried to the brain
2. the ability of the eye to focus upon objects at different distances
3. an arrangement of light rays according to their wave lengths
4. a curved piece of glass which makes light rays spread apart
5. a curved piece of glass which makes light rays come together at a focus
6. a person whose eye focuses an image sharply in front of the retina and who for this reason can see well only those objects that are held close to his eyes
7. an opening in the eye through which light rays may enter
8. a person whose eye focuses an image sharply behind the retina and who for this reason can see well only those objects that are held farther away from his eyes
9. light that has "bounced" from some surface after leaving its original source
10. the inner lining of the eyeball which contains light-sensitive cells made up of rods and cones
11. the doughnut-shaped screen of the eye which surrounds the pupil and thus controls the amount of light that may enter the eye
12. the transparent covering in front of the pupil and iris of the eye
13. the point at which light rays are brought together (or seem to be brought together) by a lens

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase. DO NOT MARK THIS BOOK.

1. Light is a form of . . . that travels in . . . lines.
2. The speed of light is about . . . miles per second.
3. The longest visible light rays are . . . in color, and the shortest are . . . in color.
4. Light rays entering the eye are bent by . . . and are focused on the . . . when vision is normal.
5. Lighting of good quality is free from . . . and . . . .
6. . . . a lamp is one way to prevent glare.
7. A . . . lens is used to correct the defect of farsightedness.
8. A . . . lens is used to correct the defect of nearsightedness.
9. When you are writing, the light should come . . . . In this way glare and . . . on your work will be avoided.

GOING FURTHER

In the Laboratory and Field

1. *Experimenting with lenses.* The *focal length* of a convex lens is the distance from the lens to the image it forms. Hold several lenses, one at a time, near a piece of white paper pinned to the wall, moving the lens forward or back until a sharp picture (image) appears. Now measure the distance from the lens to the wall. Compare the sizes of the images made by lenses of different focal length.

2. *Measuring amount of light.* Borrow a light meter from your science teacher

and then measure the strength of the light in various parts of your home. Test with the light bulbs you would regularly use and then make more tests, using larger or smaller bulbs until you get the amount of illumination that is (*a*) most comfortable and (*b*) recommended in the first reference in "Adding to Your Library," below. Compare all these figures and draw some conclusions about the lighting in your home. Have you any changes to recommend?

3. *Testing your eyesight.* If the giving of eye tests is not a regular part of your school program, get an eye chart and have your teacher test the eyes of all the pupils in your class. If you do not have eyeglasses and this test shows you need them, see your eye doctor as soon as possible. Even if you have eyeglasses, this test may show that you need new glasses or even that you no longer need them. But do not stop wearing them without getting permission from your doctor.

4. *Dissecting an eye.* The eye of a steer is similar in many ways to a human eye. Get one from your butcher. Cut it open with a thin, sharp knife. If you use a razor blade, mount it in a holder so you will not cut your fingers. Try to identify each part of the eye. Remove the lens.

Put on Your Thinking Cap

1. How can you get the best lighting for reading, studying, or some other seeing task?

2. Why may a larger quantity of light alone not give you comfortable seeing conditions?

Adding to Your Library

1. *Recommended Practice for Residence Lighting*, prepared by a committee of the Illuminating Engineering Society, 1860 Broadway, New York, N.Y., 1953. This is an authoritative bulletin with excellent tables and charts showing what kind of lighting should be found in every room of your house. It is technical but not too hard to understand.

2. *Experiments with Light* by Nelson F. Beeler and Franklyn M. Branley, Crowell, 1958.

3. *Contemporary Lighting* by a committee of the Illuminating Engineering Society (address above), 1950. If you want to be a good interior decorator (see "Careers for You"), you will want to read this bulletin on how to use lighting in home decoration.

4. *Signaling*, a Merit Badge Handbook, Boy Scouts of America, New Brunswick, N.J. This is a booklet that will help you to make use of light for the exchange of ideas.

A Bit of Research

Call upon the local public service which supplies electricity to your home. Ask for information about the correct use of lighting and then make a survey of the lighting conditions in your home or school. You may be able to bring about better seeing conditions. Sometimes it isn't the lights but the seats in a room that need to be adjusted for better seeing comfort. Sometimes more windows or new lampshades are needed. Stop taking your seeing conditions for granted. Find out how good or bad they really are.

Careers for You

A college professor told us not long ago that there is a great field for young people in the science of optics. This is the study of the use and control of light. You may find it will be interesting for you to study optics. Ask your guidance teacher for a list of the jobs that make use of light in fields of *interior decoration*, *signaling*, *staging*, and *advertising*.

CHAPTER 28

Sending and Storing Signals

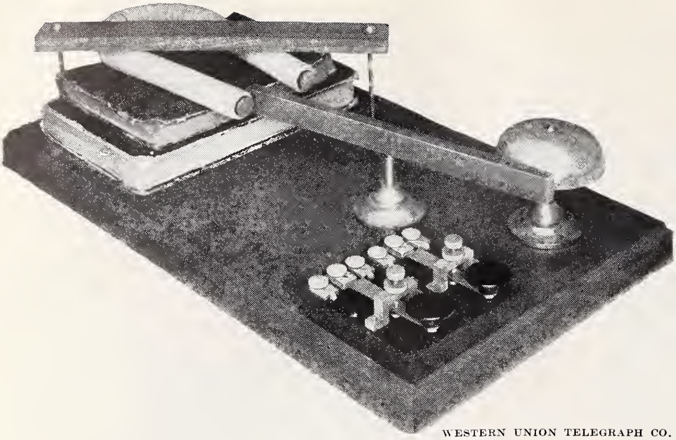
"What hath God wrought?" the first words by telegraph. "Come here, Mr. Watson, I want you," the first words by telephone. The letter *s* (··· in code) the first signal by wireless. What wonderful advances followed!

TO EXCHANGE IDEAS — that is, to get in touch with others quickly — has always been a goal for man. The jungle tom-toms, the smoke signals of the North American Indians, the beacon fires of people in olden times, the semaphore telegraphs of Napoleon's day, and the Pony Express were all invented and used to speed up communication between men.

As early as 1730 the Englishmen Stephen Gray and Granville Wheeler sent electricity through 886 feet of wire. Looking back, you would think that in another six years or so someone would have invented a simple, practical telegraph. Why then did it take 106 years?

Part of the answer is that in those days scientists did not know of each other's work as quickly as they do now. Another reason is that scientific ideas can be put to work only after they have been tested in a laboratory. Many years of experimentation were needed to solve the problems of sending messages by electricity. You will see how some of these problems were solved as you read this chapter.

The three problems that must be



WESTERN UNION TELEGRAPH CO.

304 Joseph Henry invented this electric gong. Note the moving armature and the electromagnet. Compare this with a modern electric gong, such as the kind used in schools.

solved by anyone who wishes to use electricity for sending messages, or — as we shall call it — for communication, are:

1. What kind of sender or transmitter is needed?
2. What kind of receiver is needed?
3. What is to carry the signal from sender to receiver?

The telegraph, the telephone, radio, and television each make use of different answers to these three main problems.

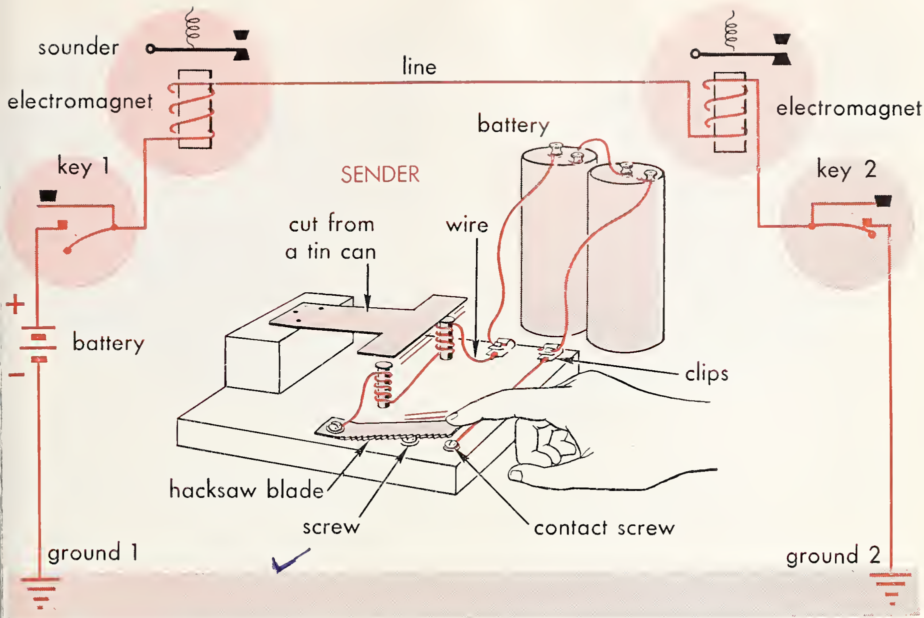
THE TELEGRAPH

The success of Gray and Wheeler in 1730 suggested the first answer to question 3. It was to send energy — electricity — along a wire connecting the sender and receiver. The thing to remember is that in those days wire was not made as it is today. A person wanting to use some for conducting electricity first had to find a way to insulate it, that is, to keep the electricity from running wild. Even a hundred years later Joseph Henry had to wind silk by hand around the wire he wanted to use to make an electromagnet (Fig. 304).

But where would one get the electricity? In the 1700's and early 1800's there were no power stations or batteries to provide electricity as we have today. Early workers with electricity had to use static electricity (p. 476). Later they could use the steady current from chemical cells (pp. 479–480). Since you have already learned about the discovery of electromagnets, you will find it easy to understand how the invention of the electric gong led to the first telegraph.

Joseph Henry, an American scientist teaching at the College of New Jersey (now Princeton University), first produced a very simple electric bell. He put together an electromagnet, a swinging iron bar, and a bell in a way that made it possible to ring the bell (Fig. 304). Of course he had to send an electric current through the wires of the electromagnet. It remained for Samuel F. B. Morse, an American portrait painter, to use Henry's invention.

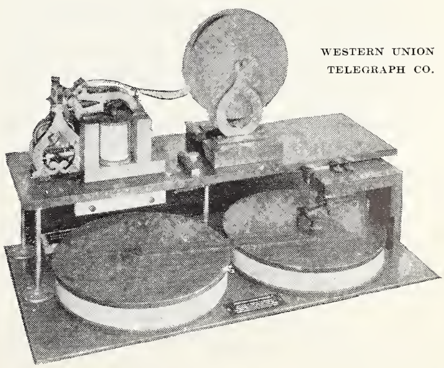
Morse learned about the invention of the electric bell and went on to invent the first practical telegraph. The main parts of a simple telegraph are: (1) a key (which is just a special



305 A homemade telegraph key and sounder (*center*). *Project:* With one of your friends, build two similar sets and connect them as shown in the wiring diagram. All the parts needed are easy to get. If your sets are connected as shown, you will be able to exchange code signals. You will need to hold your key down to receive messages. Why?

kind of switch to turn the flow of the electric current on and off); (2) a source of current (one or two dry cells will do); (3) wire (to carry the current from the sender to the receiver); and (4) a receiver. The simplest receiver need have only two parts, an electromagnet and a moving *armature*. An armature, you remember from your reading in Unit 7, is a piece of metal that is set so that it can move back and forth. Being made of iron, it is attracted to the electromagnet when the current is turned on. When the current is turned off, a spring pulls the armature back to its first position. It should not be hard for you to make your own telegraph set (Fig. 305).

Morse's first telegraph made marks on a moving roll of paper (Fig. 306). The famous first message sent by Morse in 1844 said in a code that Morse invented, "What hath God wrought?" The message was received as a series of dots and dashes. Soon



306 In 1844, Morse was using this kind of receiver. Operators soon learned to listen to the clicks and no longer needed the tape.

the operators found that they could get the message merely by listening to the clicking of the armature as it was attracted to the electromagnet. This was frowned on at first, but later the armature was made so that it would cause a loud clicking noise. The receiver then became known as a *sounder*. Ever since, telegraph messages have been sent and received by people trained to understand the sound of the dots and dashes of the telegraph code.

The idea of having a mechanical receiver print out the message was brought back in 1855, when David Hughes of Kentucky invented a method of having the actual letters of a message printed on a tape. The telegraph messages you receive today are printed in this way, and the tape is pasted to a message blank. It is not hard to train an operator to receive messages of this kind. Of course, the telegraph now in use differs as much from the one invented by Hughes as a modern typewriter differs from one your grandfather may have used.

The Telegraph Lines Grow Longer

You may wonder why Morse's telegraph was so much better than earlier ones. For one thing, it was faster. More important, it could be used over greater distances because it could make use of a *relay*, another invention of Joseph Henry. You may never invent a better telegraph, but you should know how a relay works. It is an important part of many pieces of electrical equipment.

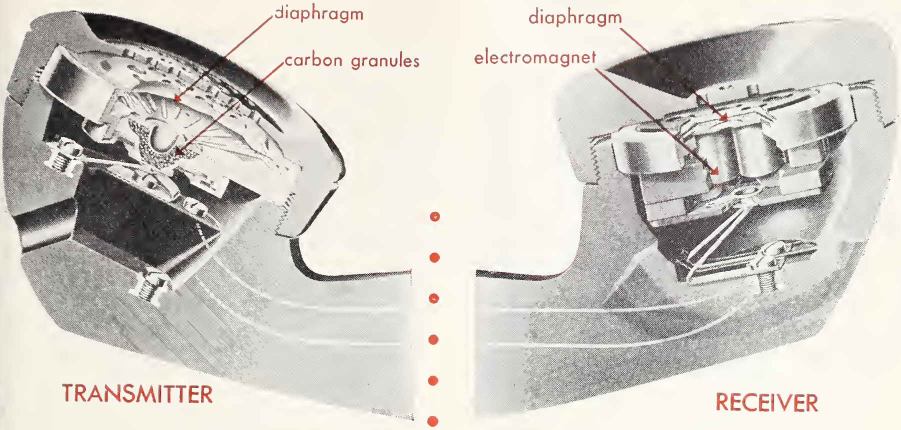
A relay may rightly be called an electromagnetic switch. It is needed when the distance between the sender and the receiver is very great. Its main parts are an electromagnet, an armature, and electric contact points. Often it also has a spring, which returns the armature to its first position when the current is turned off.

Let us see what a relay does. A long wire between sender and receiver cuts down the strength of an electric current. At a certain point a relay must be wired into the line. The weak current is still strong enough to move the armature of the relay. This closes the contacts. When the contacts are closed, a new circuit is completed. Now a new, strong current is sent into the long telegraph line. The invention of the relay made possible the extension of telegraph lines across the entire United States. Today, similar relays, using radio tubes or transistors, strengthen the weakening signals.

Now it is possible to send 288 messages over a single pair of wires at the same time. Telefax is another new development. With this invention, a telegram, picture, drawing, or letter is put into a slot and sent as a picture almost as in television. In addition to this, the telegram may be read to you over the telephone, an instrument that was not invented until after the first telegraph made by Morse had been in use for over thirty years.

THE TELEPHONE

Perhaps you have never thought of your telephone as a talking telegraph, but Alexander Graham Bell thought so. The title on his application for a patent on his first telephone was "Telegraphy" (teh-LEG-ruh-fee).



307 A modern telephone instrument. What does each labeled part do? What part operates somewhat like the telegraph receiver?

As you will see, a telephone is in some ways like a telegraph. It uses two wires to connect the sender and the receiver. It uses an electric current, and it uses electromagnets. It is an instrument with almost 500 parts and many more pieces of equipment in central stations and repeater stations. But the way your telephone works is not hard to understand.

At the Sound of Your Voice

The part of your telephone that you speak into is called the *transmitter* (Fig. 307). The transmitter changes the sound waves made by your voice into a flow of electric current to match the sound of your voice. This is done by having the electricity flow through a small box which has tiny grains of carbon in it. When these grains of carbon are pressed together more tightly, more electricity can flow through them. When they are less tightly pressed together, a smaller amount of electricity can flow through them.

The top of the box holding the carbon grains is a lightweight cone of metal about two inches in diameter. It is called a *diaphragm* (DY-uh-fram). This diaphragm is just inside the top of the transmitter. As you talk, the sound waves push against the diaphragm, which pushes against the grains of carbon. As your voice sends out strong and weak vibrations, the diaphragm will vibrate strongly or weakly. Therefore, the current sent through the box of tiny grains of carbon will be stronger or weaker, matching the vibrations of the diaphragm. Thus the sound of your voice controls the flow of electricity. The different sounds you make with your voice cause differences in the way the carbon grains are packed together. If you were to read this sentence into a telephone, the current would change many hundreds of times as each word was read.

Now all that is needed is a receiver that can change the changing electric current back into sound waves like those made by your voice.

Reproducing Your Voice

The reproduction of your voice is done by the telephone *receiver.* In the receiver there are two main parts, another metal diaphragm and an electromagnet. This diaphragm is flat and bends easily. It is also a magnet. As you notice in Fig. 307, the electric current reaches the electromagnet just below the metal diaphragm. One moment the electromagnet pulls the diaphragm closer, and the next moment it lets the diaphragm spring away a bit. This causes the diaphragm to vibrate just the way your vocal cords vibrated as you spoke into the transmitter.

Since your voice made the first sound waves, it can be said that the receiver is reproducing your voice. This is done so well by modern telephone receivers that the person listening not only hears a voice but he is able to know that it is *your* voice.

Has the sound of your voice traveled over the wires? No. It has only been reproduced. Your voice merely changes the electric current. Thus the wires carry what scientists call a changed or modified electric current. The great success of the telephone led inventors to look for other ways to communicate by means of modified electric currents.

To speak by telephone is no doubt the most commonly used way of exchanging ideas quickly when people are at places which can be joined by wires. Soon wires will carry telephone messages between North America and Europe. It is not practical to link a ship at sea by telephone line to a place on shore, nor is it possible to connect telephone lines to fast-moving automobiles or trains. However, you can pick up your telephone and talk by phone to someone a thousand miles or more away on an ocean liner, in an auto, or on a train. How is this possible? The answer is by telephones joined by radio (Chapter 30).

Storing Sound

Have you heard a wonderful musical performance, a fine poetry reading, or an impressive speech and wished that you could hear it again? Probably you can, for now we have many ways of storing sound. Without them, the sound is gone forever.

Sound, you remember, began with vibrations. On a sound recording we store vibrations and we can use them again and again to reproduce the original sound when and where we wish. Sound recording began with Edison's talking machine.

Talking Machines — Then and Now

Edison's first talking machine had few parts. It was just a metal cylinder with a means for turning it. To this was added a short, cone-shaped speaking tube with a blunt needle held to a thin diaphragm at the narrow end of the speaking tube. To make a recording, a person had to shout into the speaking tube while someone else turned the handle. This handle turned the cylinder, which was covered with a sheet of tin foil. As the sound waves moved the diaphragm, the diaphragm vibrated the needle. The needle pressed into the tin foil little grooves which recorded the vibrations. To play back the recording, Edison returned the needle to its starting point on the cylinder and again turned the handle. The

sound that came out of the tube as the needle now moved the diaphragm could be recognized as the words which had been shouted into the tube.

People had never before heard the human voice reproduced by a machine. Edison's invention seemed like magic! Actually the sounds coming from the speaking tube were terrible. One or two playbacks were all that could be expected before the recording wore off. Of course, Edison himself noted these faults, and he set to work to correct them. So did scientists and engineers who followed him. Here are some of the improvements which have been made in talking machines and sound recordings:

RADIO CORPORATION OF AMERICA

308 Styles change in sound recording and reproduction just as they do in clothing. If you look in your attic, you may find a phonograph like this one, which was popular 40 or 50 years ago.

1. Wax, glass, paper, and plastic materials have taken the place of the tin foil.

2. Except on older office recording machines (used for the temporary recording of messages to be copied by a typist), cylinders have been replaced by plastic discs.

3. A master recording disc of metal now makes possible the production of thousands of perfect copies. The disc recording you buy is made by heating an easily molded material and then pressing it against the master record.

4. The machines for making the records and for playing them back are all turned by electric motors, not by hand. This gives us a constant speed.

5. The shape of the horn was improved many times until all horns were replaced by loudspeakers like those used in radio receivers.

6. Phonograph needles have been improved to reduce wear and tear on the record as well as to last longer. Some needles may be used from 400 to 1,500 hours of playing time. These are tipped with a diamond. In spite of advertising claims, most jewel-tipped (sapphire) and precious-metal–alloy needles may damage records after only 15 hours of playing time. It is important to avoid damage to expensive records, especially those of the long-playing type.

7. The "hill and valley" type of needle groove has been replaced by a groove that moves the needle from side to side. Since these wavy grooves are all of the same depth, they wear better and the sound is improved.

8. Long-playing records and automatic record changers have added to the pleasure of listening to recorded music.

9. A recent popular development is called hi-fi, which means "high-fidelity sound reproduction." Hi-fi equipment is meant to do away with three things that reduce listening pleasure. These are noise, distortion, and lack of balance. Noise is any

UNESCO "COURIER"

309 A tape recorder is shown in use here. As the girl speaks into the microphone held in the officer's hand, a magnetic pattern is made on the tape. Just flip a switch to play it back.

extra sound such as a scratch, crackle, hum, or hiss. Distortion is any unwanted muffling, harshness, roughness, or shrillness. Balance, in the reproduction of the sound, means not too much or not too little stress on certain sounds.

10. The latest development in sound recording is called "stereo" or stereophonic sound, which really means deep sound. Actually, experiments in this type of recording have been going on for nearly fifty years, but only recently has the technique been good enough to market. In this method of recording, two sound recordings are made at the same time from different angles. Both are combined on a single record, but when the record is played two or more different loudspeakers reproduce the sounds. These speakers may be placed in different parts of the room. The effect is like that of being in the room where the original sounds were created. Stereo records must be played with a double needle because the sound waves are recorded as two separate tracks of grooves.

All these improvements have added a great deal to the popularity and enjoyment of sound recordings. Radio stations have libraries of records of music and sound effects. They also have records called transcriptions of entire programs which may be used for rebroadcasts. Do you have recordings of relatives' and friends' voices? How many ways does your school use recordings? Inventors are still at work seeking new and better ways to preserve and reproduce sounds of all kinds.

Storing Electrical Signals on Tape

Each sound is usually a mixture of many sound waves of different frequencies. A *series* of sounds is even more complex. To record and store these accurately is not simple.

Sound, as you have seen, can be stored on records, and it can be used to make electrical signals as in the telephone. But can sound be stored as electrical signals? Such signals are difficult to capture and keep because electricity leaks away. You already know from pp. 485–488 that electrical signals can have an effect on a magnet and cause magnetic changes. In a tape recorder we can store the changing pattern of electrical signals as magnetic changes on the tape. These give us a long-lasting record. The tape can, like a phonograph

record, be played back many times without the sound being lost.

The tape is a narrow ribbon of plastic, coated with a thin film of iron oxide. The uncoated side of plastic tape is shiny. If you want to cut out a section or attach another one, all you have to do is to overlap the ends and cut them on a slant with a pair of scissors. Then, holding the ends so they just fit, you fasten them together with a piece of cellophane tape. This "splicing" of sounds couldn't be done with disc recordings.

To record on tape, you set the unrecorded reel and the take-up reel in the proper positions in the machine and thread the tape through the recording slot. A microphone picks up the sound waves of what you wish to record, turning them into a tiny modified electric current which flows through a "recording head." This recording head is a very efficient electromagnet. As the tape moves past the head, the current magnetizes the iron oxide on the tape, leaving an invisible magnetic pattern recorded upon it. To play back what you have recorded, you must first rewind your tape so that you will start at the beginning. You must also be sure that you change the controls from "recording" to "play back" or you will erase your recording and lose it. When using a tape recorder, be sure you understand how the controls operate.

During the playback the magnetic pattern on the tape causes a tiny current to flow in the reproducing head — which is an electromagnet, too. This current is made stronger by an *amplifier* and fed into a loudspeaker or headphones. The same recording may be played over and over again.

If you do not like what you hear, you can erase the recording. You can use a tape over and over again for a new recording when you have no further use for the old one. This is one of the advantages of tape recording.

Tape recordings do not compare with the best long-playing hi-fi or stereophonic recordings. It would be necessary to have the same carefully controlled conditions that are provided for the making of long-playing records. And this adds to the cost. In addition, the playback equipment has to be of the finest quality. Even for the best phonograph records elaborate equipment for playback is necessary to recreate sounds without losing those of low or high frequency. A certain length of groove per second is necessary to store all the signals. With tape, too, a certain amount of space is needed for each sound pattern.

As you probably know, tapes are now being used to store the electrical signals that result in a television picture. As we shall see in Chapter 30, each separate picture is made up of over 300,000 separate dots. Over 30 such pictures appear on a television screen each second. That means that nearly ten million dots or bits of information must be captured and stored each second. For that reason, wide tapes running very rapidly are needed for recording TV picture signals. At present, tape machines for recording and reproducing TV programs are large and costly.

Sound can also be stored on film by turning sound waves into electrical signals which in turn are changed into changing light signals. These light signals are photographed on the film. When run through a sound projector, the light signals are

changed back into electrical signals and then into sound signals, reproducing the original sound.

Of course, the tape recording of a TV program stores light as well as sound on tape. You have no doubt often used a relatively simple way of storing light on film.

STORING LIGHT ON FILM

What you see in an instant is gone forever unless you can capture and store some record of the light by which you see. Those wonderful moments at a party, a thrilling sports event, leaving for your first "date" — all these scenes are gone unless you can store them.

Light, as you know, is difficult to trap and store. As with elusive sound waves, we must use a long-lasting material that is influenced by light. Chemical changes in a photographic film are what we use. Like the magnetic tape, one side of the film is coated — this time with a chemical.

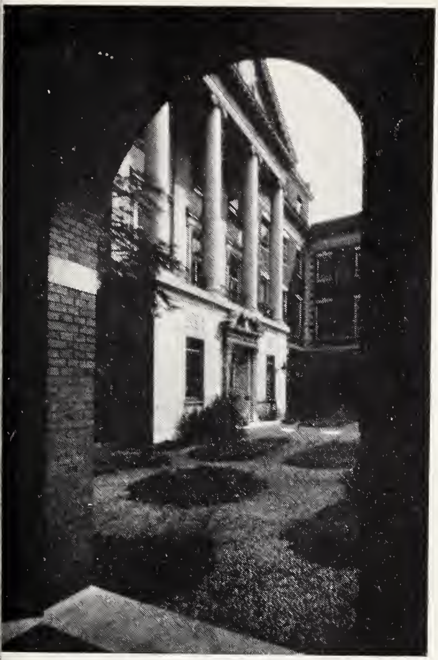
Long before anyone knew how to make a photograph, the secret of the camera was known. If a tiny pinhole is made in one side of a box and if that is the only way light can enter the box, you have a simple, pinhole camera. A pinhole camera also may be made with a lens. The picture in Fig. 311 was made with a pinhole camera.

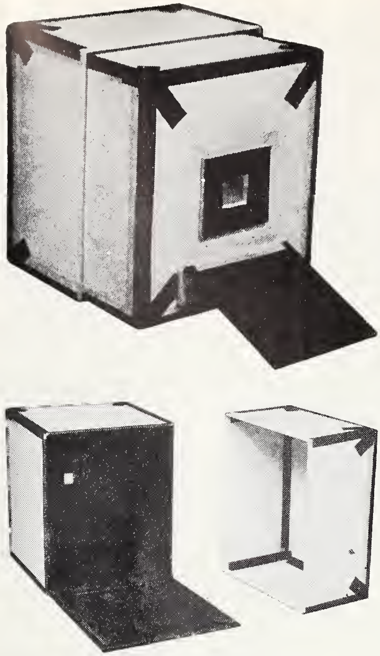
Let's Make a Photograph

We are going to start with the simplest kind of photograph — a shadow picture. Draw the dark shades and put out the lights in the room. Now, even if it is daylight outside, it is dark enough inside your room to take a piece of photographic "contact" paper out of its package for a moment without spoiling it. Contact paper is a type of paper used to print photographs. You can get a package of No. 4 or 5 contact paper in any store that sells photographic supplies. Even if you spoil one piece of this paper by look-

310 From a dark room with a small opening, people get a fine view of Seal Rocks, rugged islands located in the Pacific Ocean near San Francisco. Why is this like being inside a pinhole camera?

BY "LIFE" PHOTOGRAPHER J. R. EYERMAN, © TIME, INC.





PHOTOS COURTESY PHOTOGRAPHY MAGAZINE

11 This picture was taken with a pinhole camera. Notice that there is no moving object n the picture. With the fastest film, you must allow 1 to 2 minutes' exposure for making a icture of well-lighted scenes. A pinhole camera you can put together in an hour will make eal photographs. This camera has two half-boxes which fit together. Only one piece of cut lm at a time can be loaded into the camera. How is an exposure made?

ing at it in the light, examine it. You will see that one side of the paper is dull. The other side is smooth and shiny because it is coated with certain chemicals. These chemicals change when light strikes them.

Put on a table top the piece of paper you are going to use, with the smooth, coated side up. Lay two or three keys on top of the paper. Be sure they are separate and lying flat. Make sure the rest of the paper in the package is covered. Turn on the room lights for a minute. When you develop the paper according to the directions given in the section "Photography as a Hobby," you will find that the paper bears a white shadow picture or photographic image of the keys.

The film you put into your camera also is coated with chemicals which change when light strikes them. When you click the shutter on the camera, you let light enter the dark box and strike the coated side of the film. Since this is light which has been reflected from something or someone, you get an image of that subject on your film. However, the image does not appear until the film has been developed in certain chemicals, as described on pp. 580–585.

312 In the positive (*top*) the girl's hair and the trees appear dark, but in the negative (*bottom*) these appear light. Can you explain why?

Negatives and Positives

Let us suppose you are taking the picture of a girl (Fig. 312). As dark colors reflect little light, the trees behind her will send weak rays into your camera. Her light skin and clothes will reflect strong rays which will enter your camera. Thus the chemicals on the film will be changed very little by the weak rays from the tree and changed a great deal by strong rays from her skin, suit, and the tennis racket. In the *negative*, the girl's face and the other light objects will be almost black. Shadows will be shown by shades of gray. A negative of this kind is shown in Fig. 312. It is called a negative because it is the exact opposite of the picture you want — the photographic print, called a *positive*.

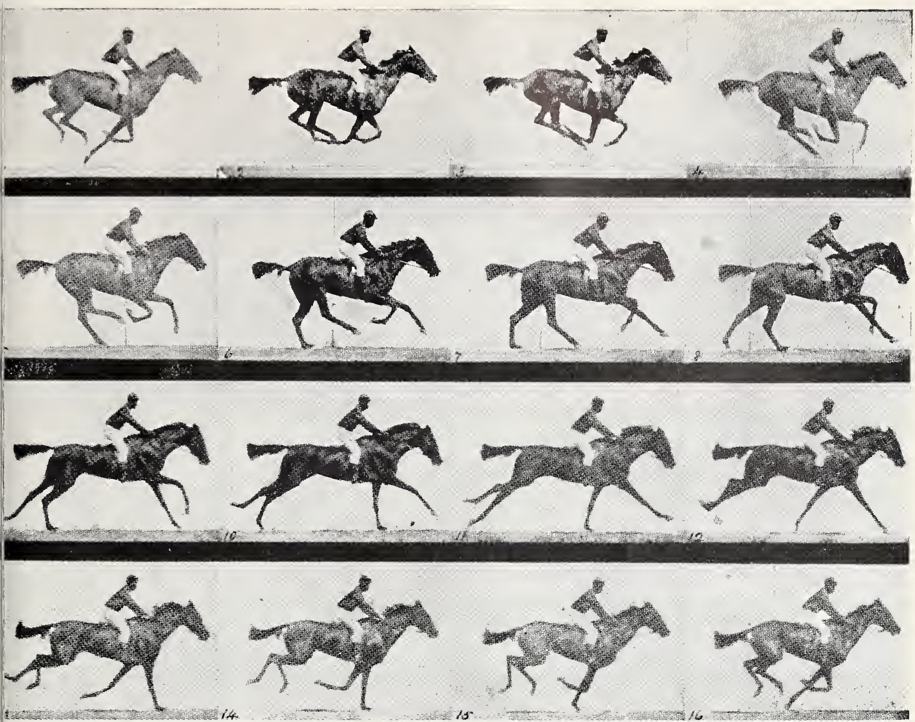
From the negative, it is possible to make positive prints. The positives are really shadow pictures like the one you made of the keys. The negative is placed on a piece of contact paper (chemically coated side against coated side). Then a light is turned on. As you can see, the light passes easily through the light parts of the negative (the tree), but the thick, dark parts of the negative (her suit) allow very little light to change the chemicals on the printing paper, with the result that you can see in Fig. 312. This is a *contact print*.

In the Polaroid-Land camera, the negative is made on paper, developed by chemicals in the camera, and printed as a positive on the paper which you tear out. Basically, it is like any other camera — only it has the chemicals "built in."

You can make both positives and negatives on film, on paper, on glass, and even on cloth if they are coated with the right chemicals, exposed to light in the right way, and correctly developed.

At this point we are not going to describe the nature of these chemicals, the kinds of film, the methods of exposing it, or the correct use of a camera. If you want to know more about photography or to take it up as a hobby, you should read the section "Photography as a Hobby" at the end of this chapter. Get started in photography as soon as you can.

Ask your teacher to let you look at some lantern slides. Also ask him to



AMERICAN MUSEUM OF NATURAL HISTORY

13 The first motion picture was a series of 24 ordinary photographs, of which 16 are shown ere. These pictures were taken in rapid order when the horse's body pushed aside thin strings ttached to the shutters of 24 cameras set up in a row.

let you examine all the parts of a slide projector. Your teacher may also have a smaller projector for showing a smaller-size slide. This 2×2 inch slide is really a holder for a small piece of film. A smaller projector commonly in use is suitable for showing a strip of pictures printed on a length of 35 millimeter (abbreviated mm.) film, known as a filmstrip. It may surprise you to find that the pictures on these film slides and filmstrips are positives and not negatives.

Photographs are usually printed on paper from the film negatives. It may not have occurred to you that from the film negative a positive can be printed on film. This may be done by using another film to obtain a transparent contact print. Color pictures are made by reversing the image on the film negative by means of chemicals so that it becomes a positive (Fig. 312). These positive prints may be made on glass or film, both of which allow light to pass through. Film slides and filmstrip are positives which you can show and make larger by putting into a projector. An important use for positives printed on film is to make moving pictures.

The First Moving Pictures

The first motion pictures were not printed on film. They really were dozens of drawings, each a little different, printed on paper like ordinary pictures. They were arranged on a wheel that could be turned by a crank. Some of the first photographic motion pictures were made by an English photographer, Eadweard Muybridge (ED-werd MY-brij), to decide a bet of $25,000. The story is unusual: the bet was made by Governor Leland Stanford of California.

Governor Stanford believed that at times a horse, while galloping, has all four feet off the ground. Other people were just as sure that a horse does not do this. Neither side had proof because the feet of a galloping horse move too quickly for the human eye to follow. Of course, a motion picture would have supplied the answer, but in 1872, when the bet was made, no motion picture camera existed. So Stanford hired Muybridge to solve the problem.

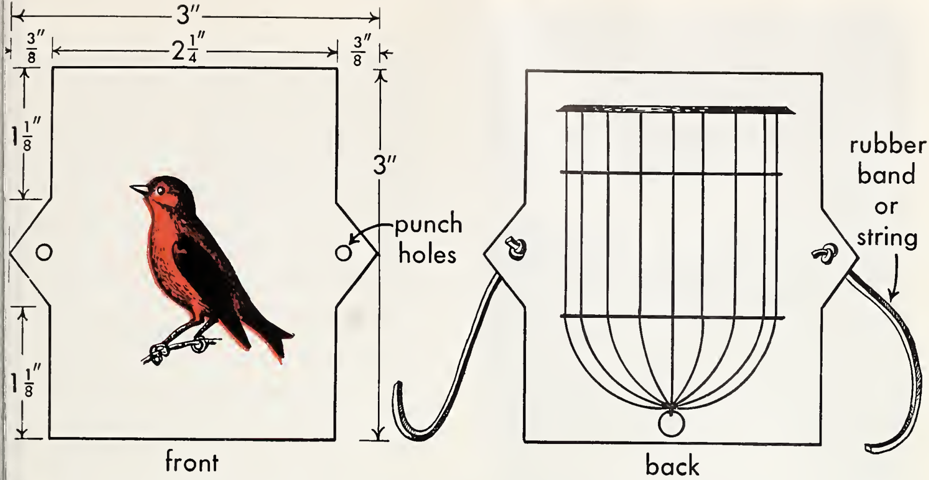
314 Animated cartoons to show a series of actions are easy to draw. Fasten them together, and you will have your own movie "flip booklet" to illustrate persistence of vision.

Muybridge set up 24 ordinary cameras in a row and ran long, thin strings from their shutters across the racetrack. The strings were arranged so that, as the horse galloped through them, the camera shutters snapped open and then closed. Thus 24 pictures of the galloping horse were taken in rapid succession. Several of the pictures showed all four of the horse's feet raised off the ground (Fig. 313), and Stanford won his bet. But you have heard only half the story.

All 24 pictures were mounted in a round frame somewhat like the toy that children still enjoy using. When the frame was spun — presto, the horse seemed almost to be galloping. It was probably the first time anyone had seen a photographic moving picture of a live animal in action.

For the next ten years, Muybridge used the same arrangement of cameras to take photographs of people and animals in motion. In other parts of America and in Europe, inventors began to think of better ways to show motion pictures. One early method is still used in the penny-arcade movie machines. The viewer turns a handle which makes a set of post-card-size photographs flip past a viewing window. As the viewer looks (peeps) into the window, he gets the idea of motion just as you can when you flip the pages of a flip booklet as shown in Fig. 314.

When Muybridge made his photographs, cameras were loaded with coated glass plates that became the negatives. In 1892, George Eastman found a way to coat photographic chemicals on celluloid. Soon Thomas A. Edison and his associate W. K. L. Dickson had invented a machine for



15 *Project:* Draw the cage and bird as shown. (The cage is drawn upside down on the back f the card.) Twist the rubber band or string. The card will twirl when you pull on the twisted ands. What principle will you be illustrating?

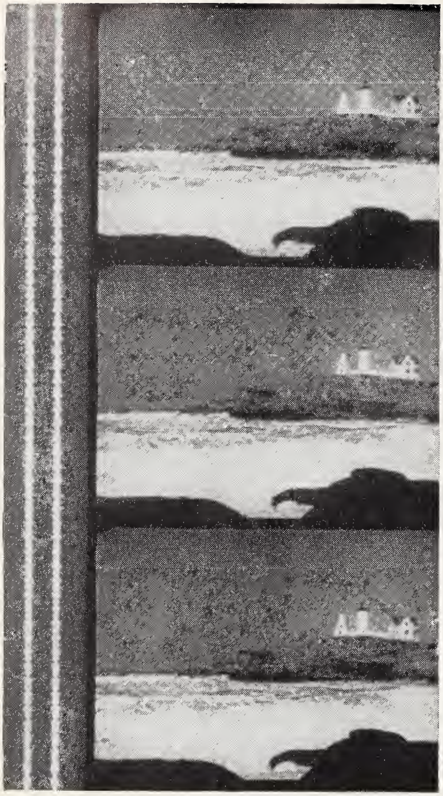
viewing motion pictures printed as positive transparencies on a reel of film that moved. Still only one person at a time could view the "peep show," as it was called. Edison also developed a camera for taking the pictures so that a whole set of cameras such as Muybridge used was no longer needed. By 1894, Edison had a "movie show" in a store on Broadway in New York City. Soon whole audiences were able to enjoy the illusion of seeing shadow pictures in which there was motion. What causes this illusion?

Persistence of Vision

By an illusion we mean a trick played on our eyes. With motion pictures we are tricked into believing we see motion when there really is none in the picture. The only thing that is in motion is the film going through the motion picture projector. This throws one picture after another on the screen so quickly that the whole series of images seem to blend. The blending of pictures takes place whenever we see one after another in less than 1/16 of a second. The blending of pictures or images is due to an effect known as *persistence of vision.*

By making the simple device shown in Fig. 315, you can test your own persistence of vision. If you whirl the card rapidly enough, the bird will appear to be sitting in the cage.

Can you explain why the bird seems to be in the cage even though it is drawn on one side of the card and the cage on the other? When we twirl the card fast enough, we see the bird for less than 1/16 of a second. Before the end of that time, the cage is in view. Since the memory of the image of the bird persists or lingers in our mind until we see the cage, we believe we see the bird sitting inside the cage. This simple effect helps explain the illusion of motion we get with motion pictures. Persistence of



AMERICAN PETROLEUM INSTITUTE

316 The sound track on a motion picture film is the area to the left of the three pictures (called frames). Examine the track with a magnifying glass. You will see it is an irregular pattern. Why is there almost no difference in the three pictures?

vision makes it possible for us to have this illusion.

Making Movies Talk

People were not satisfied with motion alone. They wanted to hear their actors talk and sing. They also wanted to hear the natural noises of the surroundings. How was sound added to motion pictures?

The answer to this question might well begin with a small piece of motion picture film such as is shown in Fig. 316. Do you see the uneven track along the left-hand edge? That is called the *sound track*. As you can see, it is a picture of light and dark areas with a saw-tooth pattern. This design was made by a ray of light moving back and forth very quickly across the width of the sound track. The beam of light was connected to a device which moved back and forth in time with the changing sound vibrations picked up by a microphone. Thus the sound track is in a way a photograph of sound waves.

The next step is to reproduce the original sounds. As the sound track runs through the projector, a light sends a tiny beam through the sound track. This light beam, which brightens or darkens according to the pattern of the sound track, strikes a *photoelectric cell*. This cell changes the flickering beam of light into an ever-changing current of electricity. When amplified, this current operates a loudspeaker. As in a radio or telephone receiver, it reproduces the sound waves in a form that is reasonably true to life.

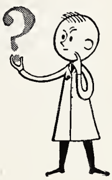
To understand how it is possible for a photoelectric cell to change light into electricity, you will have to study advanced science. But this much is not hard to understand. In 1887, Heinrich Hertz (p. 606) discovered that certain substances give off a weak electrical current when they are struck by a beam of light. This discovery led to the invention of the photoelectric cell, which is sometimes called an electric eye.

Besides being used in projectors of sound motion pictures, photoelectric cells have many uses. For in-

stance, a photoelectric cell may be used to open a door. Have you ever walked up to a door in a store or railroad station, only to find that it opened before you could touch it? As you walked up to the door, your body broke a beam of light which had been focused on an unseen photoelectric cell. This started the flow of current through a special type of relay. This, in turn, started an electric motor which opened the door. Photoelectric cells are also used in certain types of burglar alarms, as safety devices on elevators, and in photographic exposure meters. Later you will find that a television camera is really a kind of photoelectric cell. Look around and see if you can find other uses of photoelectric cells.

Our human abilities to see and hear are wonderful. As you have seen, we have also learned how to store sound and light as vibrations, as magnetic changes, and as chemical changes. In addition, we have discovered how to send complex messages long distances over wires. By speeding communication in these ways, we know what is going on over the world almost instantly and, if we wish, can record these happenings for future hearing or viewing.

We know, too, how to increase, or amplify, electrical signals and control them in many ways. Two other means of speeding communication are yet to be discussed: radio and television. But first, in the next chapter we shall explore electromagnetic waves that travel with the speed of light, without which the electrical signals produced by radio and television could not be broadcast.



LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

transmitter	photographic negative	persistence of vision
receiver	relay	photoelectric cell
photographic positive	diaphragm	sounder
armature		

1. the part of a telegraph receiver which is hit by a moving armature
2. any device for receiving a message
3. a picture in which black objects appear white and white objects appear black
4. a device used to open and close a circuit by a distant operator
5. a device for making an electric current by shining a light upon it
6. a thin piece of metal or membrane which is caused to vibrate in a transmitter or receiver

7. an effect which lets us keep a mental image of things seen for $\frac{1}{16}$ of a second after they have gone from our sight

8. a piece of metal which is held in a way that permits it to move when acted upon by a magnetic field

9. a print made from a photographic negative

10. a device for receiving or reproducing a signal

Test Yourself

In your notebook, complete the following sentences with the correct word or phrase.

1. Muybridge made the first pictures of . . . by allowing a horse to trip the shutters of a set of . . . .
2. For his first experiments with electromagnets, Joseph Henry's best source of electric current was . . . .
3. When developed, a piece of photographic paper or film turns . . . or . . . wherever light has hit it.
4. A moving armature is used in some telegraph receivers to hit a . . . , which makes dots and dashes.
5. The light colors of an object appear . . . on a photographic negative.
6. In a relay an armature is used to close or open . . . .
7. The effect of motion as you see it in the movies is an . . . .
8. The special type of switch Morse invented for sending dots and dashes is called a . . . .
9. Motion in a moving picture is due to the projection of the images of one picture after another in . . . of a second or less.
10. The flow of current through a telephone transmitter is regulated by a box containing . . . .
11. The light that passes through the sound track of a sound-on-film motion picture strikes a . . . cell.
12. The first mechanical talking machine was invented by . . . .
13. Modern tape recorders change . . . energy into . . . energy during the playback.

GOING FURTHER

In the Laboratory and Field

1. *Making a two-way telegraph.* Set up a two-way telegraph communication system with some other pupil who has also made a telegraph key and sounder. Figure 305 shows you how to make a simple telegraph set and how two of them may be connected. The telegraph key may be made from a straight piece of springy metal such as a piece of hacksaw blade. The sounder can be a T-shaped piece of metal cut from a tin box or can with a strong pair of shears. The electromagnet is easy to make from 20 to 30 feet of cotton-covered wire which is wound around two large iron nails. In connecting the two sets, do not stretch the wire across a public street or highway.

2. *Visiting a telephone central office.* If you live near a telephone central office, ask your teacher to arrange a visit. You will see there how all the telephone calls are handled by the switchboard. In the larger cities, all this is done by a few people with the aid of machines that do most of the work. Find out how to get the most use out of your telephone.

3. *Using an electric eye.* If your teacher has a photoelectric cell and the necessary parts to go with it, set it up so that it will automatically count the pupils as they enter your classroom. You might even rig a burglar alarm to protect valuable property in the school or in your home. Think up other uses for this apparatus and test them.

4. *Persistence of vision.* Draw a picture of someone or something on one side of a card and a television receiver screen on the other side of the card. Attach strings, twirl the card, and see if the picture appears to be on the television screen.

5. *Making a flip booklet.* Make a movie booklet of something in motion, such as an airplane taking off or landing. First cut out 30 or 40 pieces of blank paper 1 inch × 2 inches. On each draw a picture of the same object or scene but in a slightly more advanced stage of motion. Fasten the entire set of drawings together at one edge, as shown in Fig. 314. Then, holding the booklet in one hand, run a finger of the other hand across the open edge of the booklet. You'll see a movie.

Put on Your Thinking Cap

1. If it is possible now to send radio messages across the Atlantic Ocean, why is a transatlantic telephone cable needed?

2. What things would you regard as most important to put into a vault to be opened in the year 8000?

3. How may the use of magnetic tape recordings of television programs aid in the exchange of ideas?

Adding to Your Library

1. *Let's Go to the Telephone Company* by Naomi Buchheimer, Putnam, 1958.

2. *Using the Tape Recorder*, Curriculum Bulletin 6, 1952–1953 Series, New York City Board of Education. This booklet of forty pages is beautifully illustrated with photographs showing how to thread, use, and rewind a tape recorder. Anyone who wants to use a tape recorder in school work will find a wealth of information in this booklet.

A Bit of Research

1. Examine a brand-new phonograph needle under a microscope and compare it with other needles which you have used for various lengths of time. Find out if you can how much damage is done to phonograph records of various kinds by worn needles.

2. One of the most useful means of communicating is the electric bell or gong such as you may have in your home or school. If your teacher hasn't one of these, go to your custodian or janitor and ask to examine one. Make a complete report on the way in which the bell or the gong operates. This is something explained in many textbooks, but we think that by this time you are able to do a bit of research and find out for yourself how these things work. If you want to investigate further, find out also how the special door chimes which some people have in their homes work.

Careers for You

You may be interested in seeing these career pamphlets:

1. *Motion Picture Projectionists*, Occupational Briefs No. 279, Science Research Associates, Chicago, 1958.

2. *Photography as a Career*, Institute for Research, Chicago, 1953.

3. *Photographic Film Industry Workers*, Occupational Briefs No. 221, Science Research Associates, Chicago, 1957.

PHOTOGRAPHY AS A hobby

This section is written for the beginner in photography whose aim is to be more than a shutter snapper. But this section is just the beginning of your work as an amateur photographer. After you read it, you will need to go to the books listed at the end of the section.

There are two main steps in photography: first, taking the picture; then finishing it. Finishing includes developing the film, printing the picture, and mounting it on a suitable background. The final test of your work is the pleasure and pride it gives you and the praise you receive from others. It is a wonderful feeling to have one of your own photographs displayed in an exhibit or published.

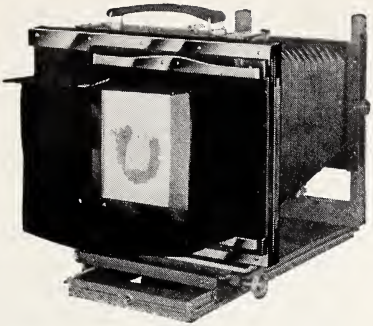
Types of Cameras

Sometimes the beginner has no choice but has to use a camera he has been given. Sometimes he has an expensive camera and sometimes a cheap one. In either case, his first job is to inspect it inside and out. Commandment number one for the photographer is: Know thy camera.

A pinhole camera (Fig. 311) is the least expensive and the least useful type, but you should own one. A sample of a picture taken with a pinhole camera is shown in Fig. 311. A pinhole camera usually has no lens, but only a pinhole to let in the light. This hole is covered with a *shutter* which is moved away when you are ready to take the picture. The camera must be loaded with film pre-cut to the right size. The loading is done by opening the box in a dark room or closet, putting in a piece of film, and closing the box again. This must be done each time a picture is taken.

Even with the fastest film, long time exposures of 30 seconds or more must be made, depending upon the brightness of the subject. Naturally more time — a longer exposure — will be needed to make a picture of a dark subject or one that is poorly lighted. Houses, parked cars, or an airplane on the ground are suitable subjects for a pinhole camera. Moving objects will not photograph at all, or they will appear blurred. For these you will need a lens camera.

Not all lens cameras can make good pictures of moving subjects. The lens and shutter must act fast enough to "stop" the action. Such pictures must be made in $1/50$ or $1/100$ of a second or less. The speed of the shutter of an ordinary box camera is about $1/40$ second. This is enough to let you take pictures of people or animals in very slow motion or standing still. A lens camera usually is made to use roll film, which is another big advantage over a pinhole camera. One loading, which does not have to be done in a



BURKE AND JAMES

317 *Left*, an expensive view camera is excellent for copying work or making portraits. The ong bellows allows different kinds of focusing. *Right*, a box camera with a fixed focus and eflex-type viewfinder. It is not to be confused with a true twin-lens camera.

dark room, permits you to take eight or more pictures.

Lens cameras may be so tiny that they will fit into a watch pocket or will fold up for easy carrying. Others, called view cameras (Fig. 317), have ground-glass screens upon which a picture may be carefully focused before the film is put in place. Some smaller view cameras can be used in different ways. They are very popular with news photographers.

Two other types of cameras are also very popular. One is the reflex, which has two lenses — one for making the picture and one for focusing. The other popular camera is the miniature or candid camera which is small, complex, and expensive. For an expert, a fine miniature camera is a wonderful tool, but we do not recommend it for the beginner. A reflex or reflex-type box camera is fine for anyone (Fig. 317).

Using Your Camera

It is hard to think of a better way to use scientific thinking than when taking pictures with a camera. First, you must be sure your subject is properly lighted. How to do this is beyond the scope of this section, but the references at the end of it on p. 585 will give you many helpful suggestions. Let us assume that your subject is properly lighted. What is the next step?

The second step is to compose your picture artistically. This means to arrange your subject and to place your camera to get the best effect. This requires a feeling for good composition, which your art teacher can help you to obtain.

The next step is to focus your camera upon the subject. With a simple box camera, no focusing is possible. You simply stand still and snap the shutter. With the more expensive camera, you have to focus before you open the shutter. Focusing means to make a sharp image fall upon the film. To focus is not difficult because there is a device on every good camera through which you can look while you are focusing. The important thing is not to forget this

step in your hurry to take pictures rapidly one after another. Sometimes better pictures are made by focusing sharply upon the main object of interest and allowing the background to be slightly out of focus.

You must also remember to use the right lens opening and shutter speed, if several choices are allowed. Now you can really experiment. Take a series of pictures of the same subject with all the different openings and speeds there are on your camera. Keep careful notes on each picture. In this way you will find out what the best combinations are for the kind of film you are using. Again, we refer you to the books listed at the end of this section for the choice of film. There are films of many kinds, and each has a special use.

Processing the Film

In the very beginning, your best idea is to let an expert process your films for you. But some day you will want to process them yourself. How do you go about it? First, you must select a suitable place — the kitchen, bathroom, or a real darkroom. If your room was not built as a darkroom, you must make it completely dark before you start to process your film. If your film is marked "panchromatic," you will have to work in complete darkness the whole time, using only your sense of touch. If your film is marked "orthochromatic," you can work with a red safelight turned on. This kind of film is not spoiled by red light.

Strictly speaking, the processing of your negative begins when you snap the shutter. The result of this simple act will be a negative that is correctly or incorrectly exposed. If you let too much light strike the negative, you will overexpose it. Your negative will come out of the chemical baths looking thick, dense, and heavy. The print you make from it will look washed out and very light. On the other hand, if you let too little light strike the negative during the exposure, the negative will be thin and transparent and the print made from it will be very dark.

But let us suppose you exposed the film correctly while it was in the camera. Will it look right when it has been put through the chemical baths? Yes, it will, if you are careful. But if you are not careful, you can damage the negative in the process. Unless you have a special reason for underdeveloping or overdeveloping a negative, you should try to develop the film just right. This means watching the time and temperature carefully. The time is given to you by the manufacturer. The temperature you must control. Developer acts faster when it is warm. If possible, keep it cool (68° F.) and clear. Now go ahead.

The general procedure is the same for most film. First, the film is given a bath in a developer. This is a chemical solution placed in either a tray or light-tight tank into which the film has been loaded. When a tray is used, hold the film by the ends and run it back and forth through the bath. This must be done carefully to avoid leaving one part of the film in the bath longer than another. Do not let the film touch another part of the film because it will stick and tear. For this reason, tank developing is the method many people prefer. Be sure of one thing if you use a tank: the spool on which the film is loaded must be *completely* dry

before the film is allowed to touch it. If it is wet, the gelatin coating on the film will become sticky and tear.

The developer bath finishes the job begun by the light rays during exposure. This bath deposits a coating of silver on the film wherever the light rays struck the chemicals of the film itself. When the developer has done its work, its action is stopped by a rinse in plain water. Next the film is washed in a hypo bath. *Hypo* is the common name for the chemical that is used. It removes from the film all the light-sensitive chemicals that were not struck by light rays at the time the exposure was made. This part of the process ends when the film has become clear enough to see through. However, to make sure the job has been done properly, twice this amount of time is usually allowed for the hypo bath. This is called fixing. If not fixed properly, the picture will soon darken and fade.

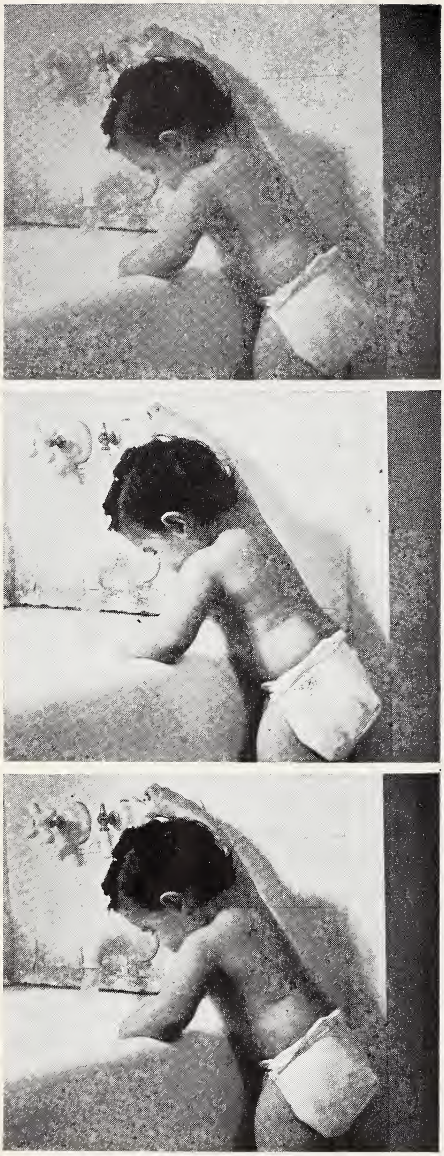
The acid in the hypo bath hardens the coating of gelatin. To finish the process, the film is washed for a long time in running water. An hour of this, and you are ready to hang the film up to dry. Put a weight on the end to prevent it from curling. After a few hours the film is ready to cut into separate negatives or into strips.

Printing by Contact or Projection

By the time you have processed your negatives, you feel your goal is in sight, but you still have to make the prints. The easiest way is to make a contact print as described on p. 571. If you own an enlarger, you can put the negative in the path of a beam of light which is then projected like a lantern slide on a piece of enlargement paper (Fig. 318). The light is turned off when the photographer thinks that the paper has been exposed long enough to the rays of light. No one can tell you exactly how long to expose a contact paper or enlargement paper to the light. You will have to learn by experience to time the exposure correctly. The time depends upon the kind of negative, the kind of paper, and the strength of the light. To save costly paper, it is best to make test strips.

Test strips are made by cutting print papers into strips 1 inch wide. First expose the entire strip for 1 second. Then cover up a portion and expose the rest of the strip for another second. Continue to cover up

318 The first step in making an enlarged print is to put the negative in an enlarger like this one. Then focus the image on a piece of paper held in a masking frame.



319 Prints should be made on the correct grade of paper. *Top*, print is too soft and gray. *Center*, in this print, details are lost because the contrasts are too sharp. *Bottom*, correct print has full range of tones.

and expose small portions of the strip at intervals of 2, 4, 8, 16, and 32 seconds. This testing in the long run will save you time and money.

You can make the best prints by choosing the correct grade of printing paper. Printing papers are graded as hard, medium, or soft. For normal negatives, medium hard papers are used. For flat and thin negatives, use hard papers. Number 1 and 2 grades are soft, 3 is normal or medium, and 4 and 5 are hard. Figure 319 shows you the difference between prints made with the correct type of paper and those that were not.

No matter how the exposure is made, the processing of prints is similar. Trays of developer, water (stop bath), and hypo (fixing bath) are arranged in a row. The print is held in the developer for the length of time recommended by the manufacturer. It is held in the first rinse for 15 seconds, in the hypo for 15 minutes, and then washed in running water for an hour. The prints are dried between blotters or in a dryer. The dried prints are finished by trimming or cropping away the uninteresting parts. Any spots may be touched up with a soft pencil. Then the print is mounted on a suitable piece of cardboard, usually white. Never exhibit poor prints or good ones that are poorly mounted. To make a good print, follow the suggestions made above, and be sure to use fresh chemicals.

Every picture in every magazine or newspaper brought pleasure or profit to some photographer. What do you think are the qualities that lead to success in photography? Do you have these qualities? If so, photography is for you. Try your hand at it and see how much fun it is.

Things to Do

1. *Building a darkroom.* Write to the School Service Bureau of either the Eastman Kodak Co. at Rochester, N.Y., or to the Agfa Ansco Corp. at Binghamton, N.Y. They will send you upon request the information you will need for building an efficient darkroom. With the information thus obtained, construct a darkroom in your home, in the school, or in a community center.

2. *Photographs for articles.* Write an article on some aspect of photography and try to sell it. You may not succeed at first, but you will learn a great deal by making the attempt. Start by studying the kind of pictures and ideas that are published by magazines such as the *Popular Science Monthly* or *Scientific American.* Then locate an interesting piece of craft work or a gadget that someone has invented. Interview the person and take pictures of his invention. In less than 500 words tell how others might make use of the idea. Submit the idea to a magazine with four or five excellent photographs of the project. Glossy prints 8×10 inches are preferred. You may be thrilled to discover that your work has market value, and you will be on your way to a paying pastime or possibly a career.

3. *School projects.* As soon as you can get your darkroom equipment and camera set up and you know how to take good pictures, look for a school or community event to photograph. For example, you may take class pictures for your school newspaper or yearbook. Various organizations in your community may welcome your help in the preparation of posters, favors, and exhibits.

Reading for the Amateur Photographer

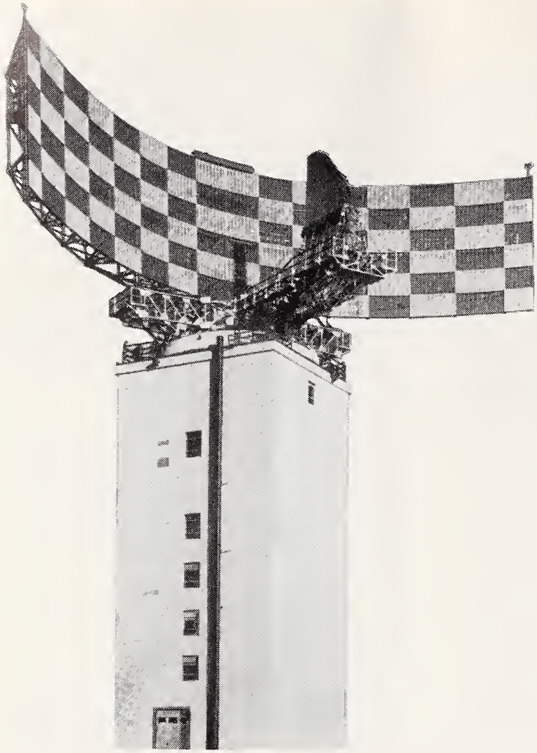
1. Get the Eastman Kodak Company (Rochester, N.Y.) Data Books on *Photographic Papers*, *Lens Accessories*, *Lenses and Shutters*, *Negative Materials*, *Color Photography*, and *Infrared Photography*. Also *Developing*, *Printing and Enlarging*, *and How to Make Good Pictures.*

2. *The Real Book About Photography* by William P. Gottlieb, Garden City (Doubleday), 1957.

3. *Photography* by R. Will Burnett and Herbert S. Zim, Simon and Schuster, 1956.

4. *Fun with Your Camera* by Mae and Ira Freeman, Random, 1955.

CHAPTER 29



Electronic Messengers

"Peace on earth" — so came the first message broadcast from a satellite. President Eisenhower's message was borne by electronic messenger.

WHICH is easier to do — get information or give it? In school and at home, you get a great deal of information from your teachers, parents, and friends. From reading, watching television, and listening to the radio you have still other ways of getting information. At best, this kind of information is secondhand and if you act upon it, you do so assuming the facts are correct and accurately reported. But sometimes it is necessary to get the facts not from a report but from firsthand observations.

For example, your tooth hurts. That's a fact and you report it to your dentist. The information is correct, but it is insufficient for him to make an intelligent decision concerning what he will do about it. The only way for him to get the further facts that he needs is to take an X-ray photograph of the tooth. Before the discovery of X rays many teeth were pulled out that could have been saved because the dentist had no way to get the kind of information he needed.

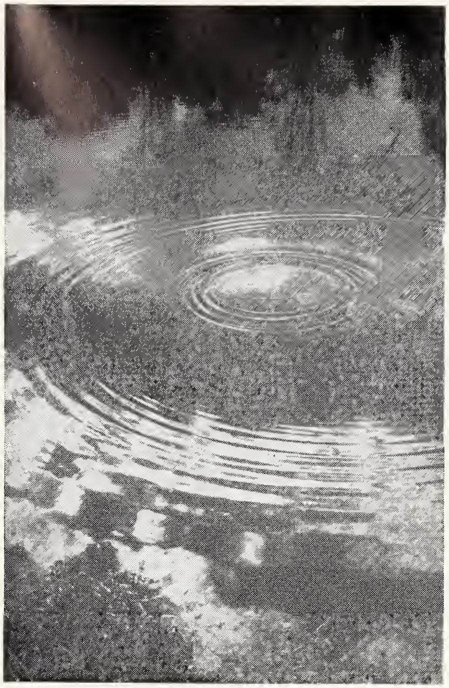
You are fortunate to be living when

it is possible to get facts by means unknown a few decades ago. Science has provided electronic messengers to bring information to you quickly and accurately. If you know how they work, you will be able to make use of them more intelligently, whatever your job. The word "electronic" may be new to you. But in Chapter 24 you learned about electrons, extremely small bits of matter with electric charges. A branch of science called electronics deals with the study of the behavior of electrons free to move in space. Under certain circumstances you will learn about in this chapter, energy, traveling in waves, is able to cause electronic and magnetic effects.

WHAT ARE ELECTROMAGNETIC WAVES?

An easier question to start with is: What is a wave? Of course, you have tossed pebbles into a pond and noticed the tiny waves spreading out from the spot where the pebble hit the water. There are many kinds of waves, but every wave is the result of some kind of disturbance from some source of energy. The kind of material through which some waves travel is well known. Water is able to carry waves, and air carries sound as you learned in Chapter 26. All waves do not travel in the same way. Some waves move along because the particles of the medium they travel in are disturbed first by a push forward and then by a push backward. A sound wave is of this kind. See Fig. 291.

Another kind of wave seems to move along because the particles of the material in which it moves rise and fall. This is the kind of wave a rope attached to a wall will make, if you shake the rope up and down. This is the kind of wave that is shown in Fig. 296.

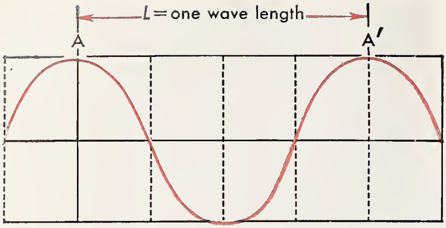


HELEN FAYE

320 If a pebble is tossed into water, surface waves will travel outward in widening circles from the point the pebble hit the water.

The water wave you caused by tossing a pebble into a pond is similar to the rope wave. It will cause a leaf to bob up and down in the same place, but the wave moves toward the shore in ever-widening circles. A water wave travels only on the surface of the water (Fig. 320), but sound waves and light waves travel out in all directions from a source.

Light waves are one type of electromagnetic wave. The other kinds



321 One complete wave length is the distance between any two corresponding points on the wave (as from A to A'). A single wave from start to finish is called one cycle. Wave lengths vary from very small to very large.

of electromagnetic waves also spread out in all directions, if allowed to do so. But sometimes, as with light waves, we prefer to focus a beam of them in one direction. You may have noticed that some electromagnetic wave equipment is shaped like the reflectors used in a flashlight or in a photo-flash device (p. 586). The way in which we use and direct electromagnetic waves depends upon their *wave length* and *frequency*.

Wave Lengths and Frequencies

So that we can talk about waves and what they do, we need to know the meaning of the words scientists use to describe them. First, the length of a wave can be measured from any point on one wave to a corresponding point on the next wave. For convenience, we can measure the length of a wave from the crest A to the next crest A′, Fig. 321. We will use the letter L as a shorthand symbol for the term *wave length*.

Perhaps you have seen water waves moving faster at one time than at another. All electromagnetic waves travel at the same speed, or as scientists prefer to call it, the same *velocity*. The velocity of these waves (v) is known as the speed of light. Careful measurements have shown this to be about 186,000 miles per second. Although all of the electromagnetic waves travel at the same velocity, the waves *oscillate* at different frequencies. The word oscillate means simply to move back and forth like the rope described in Fig. 296.

In other words, the number of complete oscillations (waves) that occur within a certain period of time — such as one second — is known as the *frequency* of a wave. We shall use the letter f to denote frequency.

In Fig. 321 you notice that a wave changes from a crest to a trough and back again to another crest. One complete change is one oscillation, but it is also called a *cycle*. We can define *frequency as the number of complete cycles that take place in a given period of time*, usually one second. If you hear someone speak of a 60-cycle wave, you know that the frequency of its oscillations is at the rate of 60 times per second. This way of speaking of frequencies holds true even though in a particular case the wave may not last for a full second.

Scientists have a very simple equation which enables you to relate these three — velocity (v), wave length (L), and frequency (f). It is:

$$v = Lf$$

This means velocity equals wave length multiplied by the frequency. We can rewrite this equation in two very useful ways.

The first gives us an equation for finding the frequency of a wave, if we know its wave length. It is:

$$f = \frac{v}{L}$$

This means that frequency equals velocity divided by the wave length.

The second is for finding the wave length of a wave if we know its frequency. It is:

$$L = \frac{v}{f}$$

This means that wave length equals the velocity divided by the frequency. Since v always equals 186,000 miles per second, only one other number is needed to find the third value.

If we know that a certain wave is 0.2 of a mile in length, what is its frequency? Since $L = 0.2$ and $v = 186{,}000$,

$$f = \frac{186{,}000}{0.2} = 930{,}000 \text{ cycles.}$$

To save writing such a large number, we would call this 930 *kilocycles* or simply 930 kc. The prefix "kilo" comes from the Greek word for 1,000. For very high frequencies of a million cycles a second, we use the word "*megacycle*" — "mega" comes from the Greek word for 1,000,000.

Now suppose you know that a certain wave has a frequency of 10 mc. — that is, 10 megacycles — what is its wave length? Of course we know that $v = 186{,}000$, so

$$L = \frac{186{,}000}{10{,}000{,}000} = .0186 \text{ mile}$$

which is roughly 0.02 mile or about 100 feet.

Some electromagnetic waves have wave lengths as short as 0.0000000001 cm. or frequencies as great as 300,000,000,000,000 cycles (Fig. 322). These figures are both hard to imagine and much too awkward to work with. Scientists and mathematicians use what is called *powers-of-ten notation*. You probably have used it too, for you know that $100 = 10 \times 10 = 10^2$ and $1{,}000 = 10 \times 10 \times 10 = 10^3$. Can you figure out why 100,000,000,000,000 is written 10^{14}?

Fractions can also be handled in the same way. A wave length of 0.00000001 cm. is the same as $\frac{1}{100{,}000{,}000}$ cm. We write this as $\frac{1}{10^8}$ cm. Do you see why? Even more simply, this number may be written on one line as 1×10^{-8} cm. The minus sign merely says that we are *dividing* 1 by 10 multiplied by itself 8 times. In the example, you will notice that the denominator of the fraction had 8 zeros. We indicated this by the small figure (^{8}) which is called an *exponent*. The exponent tells us to read the number as 10 to the eighth power. If we write 10^{-8}, we read it as 10 to the minus eighth power.

After a little practice writing numbers in this way, you will understand why scientists use this convenient method. For example, here are a few numbers written three ways — in words, in numbers with all the zeros showing, and in powers-of-ten notation:

ten billion = 10,000,000,000 = 1×10^{10}

one million = 1,000,000 = 1×10^6

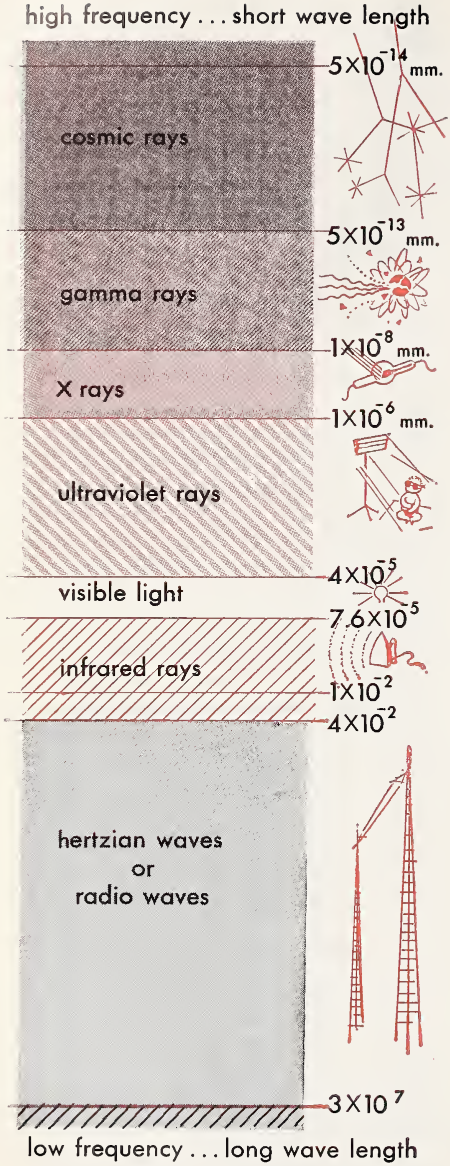
forty thousand = 40,000 = 4×10^4

six hundredths = 0.06 = 6×10^{-2}

two ten-thousandths = 0.0002 = 2×10^{-4}

fourteen hundred millionths = 0.00000014 = 14×10^{-8} or 1.4×10^{-7}.

In this chapter the powers-of-ten notation will be used to describe some of the waves used in communication. For those who are interested, we have provided more information about the



322 Our eyes are sensitive only to visible light. Waves with shorter or longer wave lengths can be detected only by their effects.

usefulness of this system of notation at the end of the chapter. See p. 601.

Recognizing Waves by Their Effects

How do we know that there are such things as electromagnetic waves? You cannot see, hear, touch, taste, or smell an electromagnetic wave. Can you see that band of electromagnetic waves called visible light rays (Fig. 322)? You may think so, but you really see only their effects. The different effects of electromagnetic waves is our evidence that such waves do exist and that there are different kinds. These effects, by the way, are not simply electrical or magnetic. Since these waves are a form of energy, they may reveal themselves by any of the common methods by which energy is changed from one form into another.

Some of these transformations of energy we can detect with our senses. In Chapter 27, you learned that your eyes have the ability to see (that is, detect) the effects of a few of these waves, the ones we call visible light rays. Your skin will show a burn or a change in its color as an effect of exposure to infrared and ultraviolet waves if it is exposed to them long enough. For the other types of electromagnetic waves, we must depend upon man-made detectors designed to reveal their effects. Among those man has invented are screens that glow when hit by certain of these waves and special types of photographic film to detect others. He also has discovered that certain minerals which can be used as paint pigments change color under some of these rays. He knows that some of the waves will cause certain metals to give up

electrons. You will read about all of these discoveries in this chapter and the next one.

Another reason we have for knowing that electromagnetic waves really exist is our ability to make some of them. A broadcasting station generates a certain type of electromagnetic wave to bring you the audio part of a television program. It generates a similar but somewhat different type of wave to bring you the video portion of the programs you like to watch. Doctors have lamps to produce infrared rays when they want to treat a patient with radiant heat in limited doses. Doctors and dentists have machines for creating X rays, too. On p. 593 you will read of an experiment in which a lamp sends out ultraviolet rays. Electromagnetic waves do exist because we can both make them and use them.

A third test of the existence of these waves is that they can be directed and guided in certain ways. In Chapter 27 you saw that light waves can be bent with a lens or reflected by a mirror. Other types of electromagnetic waves also may be focused or reflected (p. 587). For example, have you ever noticed any double-image "ghosts" on your television screen? They probably were caused by a second set of video waves from the same broadcasting station. They took a little longer to reach your receiver because they were reflected from some nearby structure before your set received them.

SHORT-LENGTH, HIGH-FREQUENCY WAVES

You remember our definition of communication is the getting and giving of information. By means of electromagnetic waves, we not only exchange and broadcast ideas but we can also get facts from hidden, remote, and nonliving sources. These waves help us to unlock the secrets of past life on the earth and of happenings in the universe many light-years away. We are still far from being well informed on these subjects. It is a region of discovery that should tempt those of you who have a taste for scientific adventure. It is also a region that offers many possibilities for a career in electronics.

Using Ultraviolet Rays

Ultra means beyond. Ultraviolet rays are the first beyond the rays of visible violet light (see Fig. 322). They are higher in frequency and shorter in length than violet light rays. As you can see in Fig. 322, ultraviolet light is really a bundle of three types of rays. All three types are contained in the rays sent out by the sun. They range from about 1×10^{-6} cm. to 4×10^{-5} cm. in wave length. The waves with the shortest wave length are called the *far ultraviolet.* Those with the longest of these very short wave lengths are called the *near ultraviolet* and those in between are called the *middle ultraviolet.* The middle rays range from 2.8×10^{-5} to 3.2×10^{-5} cm. in wave length. Both the middle and far ultraviolet rays can cause painful burns within a very short time. However, we do not have to worry about being burned by the far ultraviolet rays of the sun as long as we stay on the earth. The outer layers of the earth's atmosphere filter them out. However, they could be very dangerous to travelers in space.

CITIES SERVICE COMPANY BY FRITZ HENLE

323 A welder wears a special shield to protect his eyes from ultraviolet rays given off by the high temperature light source of the torch he uses to weld metal.

The near ultraviolet rays and those in the middle range which reach the earth can cause sunburn. The near rays alone will simply cause a suntan. If you want a tan without a burn, you should use a preparation on your skin that filters out rays with a wave length shorter than 2.9×10^{-5} cm. One with 10 percent phenyl salicylate (FEN-'l · suh-LISS-ih-layt) in a cold cream base will give protection from sunburn and help your skin to tan, if anything will. Some people just do not tan. They probably have too few color-producing cells in their skin.

Some summer day when you are sitting on the beach with your friends, you can do an interesting experiment. Instead of covering your entire arm with your own suntan lotion or cream, ask your friends to let you use a bit of their preparations. Within each area of your skin to which you apply these, leave a dime-sized spot of bare skin. You can then compare the effectiveness of all of the brands. The unprotected spots of skin serve as a control. This is not a dangerous experiment unless you stay in the sun too long, and that would be even more dangerous if you used no lotions.

Of all the parts of your body, the sensitive retina (see p. 554) of the eye is the most easily burned. Ordinary glass filters out ultraviolet rays and so, if you wear glasses of any kind or remain behind a window, you have a measure of protection from ultraviolet rays, which might burn your retina. However, if you want the best protection, you should wear sunglasses that are designed for the purpose. If you need glasses to aid your sight, the sunglasses should be ground to your prescription. You may not have known it, but sun lamps, welder's arcs, and other high temperature sources of light give off harmful ultraviolet rays. Do not count on ordinary sunglasses for protection from these sources. Most sunglasses do not stop enough rays. If you get a chance, look through the window of a welder's eye shield (Fig. 323). You will see how different it is from the type of sunglasses you ordinarily buy.

In welding, the ultraviolet rays are dangerous and certainly not useful. But used in other ways, ultraviolet rays are an important aid. For example, the shirt you send to a laundry may be given an identification mark with an ink that is invisible under ordinary light. The one who sorts the shirts in the laundry is able to see the marking when he passes the shirt

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324 Ultraviolet light reveals normally invisible laundry marks.

under an ultraviolet light. In these rays the mark glows clearly (Fig. 324). The advantage is that your shirt comes back to you without a visible mark on it.

Why did the ultraviolet light make the laundry mark glow? Certain substances that were in the invisible ink have the property of absorbing light of one wave length and changing it to light of another. The wave length of the invisible ultraviolet light was changed to the wave length of a visible color. Many minerals and dyes glow with beautiful colors when ultraviolet light shines on them. They may also glow under X rays.

When the ultraviolet or other high-energy rays are turned off, the glow stops almost immediately. If this happens, the materials are said to be *fluorescent* and the effect is called *fluorescence*. You have surely seen fluorescent lamps. The bulb has a coating of fluorescent material on its inner surface. These materials are called *phosphors* (FOSS-fors). If they continue to glow for more than a small fraction of a second after the energy used to excite the glow is cut off, the effect is known as *phosphorescence*. So you see, the difference between fluorescence and phosphorescence is the time that the effect lasts after the exciter is turned off. Ultraviolet rays are not the only means of exciting materials to glow. In the screen of an X-ray machine, the phosphors are excited by the X rays. In your television picture tube they are excited by a beam of high-speed electrons. In the new cold light panels used for room illumination (Fig. 325) the agent causing the glow is an alternating electric current.

The phosphors used in radar and television tubes and X-ray screens have to be manufactured very carefully. They get their ability to glow from tiny amounts of "impurities" which have to be controlled. Actually, there are dozens of substances including such common things as Vaseline, grease, chlorophyll, mercurochrome, naphthalene, and human teeth that will glow under ultraviolet light.

No doubt, many other uses of ultraviolet light will occur to you before we mention them. In addition to the fluorescent lamp which was first shown to the public at the New York World's Fair in 1939, ultraviolet light is used in many ways. It is employed in various kinds of scientific research, in crime detection laboratories, in detecting counterfeit documents and paintings, in military intelligence work, in advertising, in prospecting for mineral ores, in the theater for special "black light" effects, in inspecting food and gems,

WESTINGHOUSE

325 A cold light panel lights a stairway, thus eliminating danger of a fall in the dark.

in textile and dye industries, and in safety-warning devices. So you see how useful ultraviolet light is in helping people to get information which is hidden under ordinary light. Can you mention other similar uses?

What kind of waves are beyond ultraviolet? Of course, you have heard of X rays, and possibly you have heard of gamma rays and cosmic rays. All are invisible to us, but we have ways of detecting their effects.

X Rays and Their Uses

Beyond the band of ultraviolet rays is a band of rays of still shorter wave length and higher frequency. They are known as X rays. They range from 1×10^{-8} cm. to 1×10^{-6} cm. in length. They are also called *Roentgen* (RENT-g'n) *rays* in honor of the German scientist, Wilhelm Konrad Roentgen, who discovered them in 1895. Roentgen himself gave them the name X rays because at the time of their discovery he did not know their true nature, and the name has stuck. We know now that they are electromagnetic waves which are able to cause unusual effects.

Roentgen reported that he found X rays went through paper very easily. Wood, rubber, most kinds of glass, flesh, water, air, thin sheets of aluminum, lead, copper, silver, gold, and platinum will allow X rays to pass through. However, thicker sheets of metal and certain metallic salts stop or slow down the X rays so that they cannot affect X-ray film as much. These show up as lighter areas on the photograph (Fig. 326). The inside of the digestive system (Fig. 326) becomes visible because the patient has swallowed a barium sulfate "cocktail." Barium sulfate is one of the metallic salts that stops X rays. This is a striking illustration

326 X-ray photograph of part of the digestive system. The organs have been made opaque to the rays by a barium sulfate "cocktail."

JULIUS WEBER

of the way doctors put electromagnetic waves to use to get information which can be communicated to them in no other way.

By using X rays doctors are able to set broken bones, locate things swallowed by accident (such as pins and coins), and find bullets or other pieces of metal that may get into the body. They are able to locate hidden infections such as abscesses or ulcers inside the body. They can find tumors, detect tuberculosis, and tell if internal organs are working properly.

In industry X rays are used for detecting flaws in castings, for inspection of manufactured products, for discovering metallic or other objects in foodstuffs, and for inspection of crops such as oranges suspected of having been damaged by frost. X rays are also useful in locating lost or hidden objects and in determining whether some objects such as paintings are genuine or fakes.

These uses of X rays all help to communicate information to us. There are other uses of X rays in the treatment of disease such as cancer, which is not the subject of this unit, and in atomic research which you read about in Chapter 15.

Tiny as X rays are, they are not the smallest electromagnetic waves. There are two kinds that are even smaller and more highly packed with energy. These are the gamma rays and cosmic rays.

Gamma Rays and Cosmic Rays

Gamma rays are electromagnetic waves ranging in length from 5×10^{-13} to 1×10^{-8} cm. The most useful sources of these rays are the radioactive elements. The use of these elements as tracers has been described in Chapter 18. They supply us with valuable data in a wide variety of situations.

Gamma rays are true electromagnetic waves, but cosmic rays act as if they were small particles moving at the speed of light. This may well confuse you. There is a large branch of physics dealing with this subject. Studies started less than 50 years ago indicate that an electromagnetic effect may be caused by waves or particles or both. You will have to take our word for it because a further explanation would be a story too long for this book. It is also a complicated and difficult subject which you will be better able to understand when you study high school physics.

Cosmic rays consist of particles from outer space that bombard the earth and its atmosphere. When they hit other bits of matter, they cause a second class of particles to be formed which are also called cosmic rays. Cosmic rays are as short as 5×10^{-14} cm. They bring us information of a different sort. They have been studied for only a short time. Knowledge of their existence, first suspected about 1900, came about because of a peculiar thing you can test yourself.

All you need is a simple piece of apparatus called an electroscope (Fig. 327). If you do not have one, you can easily make one by looping a thin strip of aluminum foil (tin foil) over a copper wire run through a cork. Place foil and wire into a flask or bottle and fit the stopper tightly. To charge the electroscope, first rub a glass rod with silk and then touch it to the exposed end of the wire. The leaves of the foil fly far apart. Or you may charge it

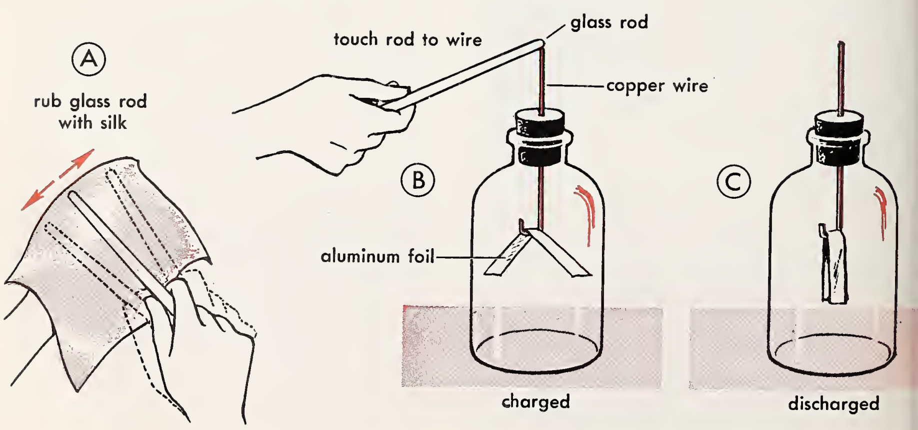
with a hard rubber rod rubbed briskly with a piece of fur or woolen cloth. The leaves are charged with like charges which repel one another as you learned in Chapter 24. They should stay apart as long as no other object is brought near the electroscope. But they do not. After awhile the leaves will come closer together again in spite of all precautions. What causes this discharge of the electroscope? Scientists have decided it must be the effect of cosmic rays.

The cosmic rays that reach the earth's surface arrive with tremendous energy. They have been counted in deep mines far below the earth and far below the surface of the sea. Scientists studying these rays are obtaining more information about the nature of matter and the universe. Various devices have been placed in earth satellites to radio information about their effects back to scientific laboratories. The study of cosmic rays is one of the new frontiers of scientific research. It is interesting to note that we are now using another type of electromagnetic wave, radio waves, to bring down to earth the new information about their distant cousins the cosmic rays. All this is possible because of the great progress made in long-wave research, which began less than a century ago.

LONG-LENGTH, LOW-FREQUENCY WAVES

Imagine yourself in the laboratory of the great English astronomer, Sir William Herschel, in the year 1800. You may repeat a test which he did at that time by using a triangular glass prism and an ordinary thermometer. Direct a ray of sunlight through the prism. Note how the ray spreads out to form a spectrum that looks like a rainbow. Now do as he did — put the bulb of the thermometer into the various colors and note the temperature at its highest. Then put the bulb into the darkness just beyond the red end of the spectrum. Are you amazed as he was with the rise in temperature?

327 You can make this simple electroscope by following the directions in the activity on this page. Then experiment with it to learn how it works.



Infrared Radiations

The reason for the rise in temperature is that there is a band of invisible radiations which are able to produce a great deal of heat energy. This band consists of infrared electromagnetic waves. *Infra* means below. Infrared rays are lower in frequency but longer in wave length than visible red light. Infrared is a broad band of waves ranging in length from 7.6×10^{-5} cm. to about 4×10^{-2} cm. (0.4 millimeter). In Fig. 322, you notice that they overlap the smallest of the hertzian waves, which start in the region of 0.1 to 0.3 millimeter. Since the infrared and hertzian waves are used in quite different ways in communication, we will discuss them separately.

About 40 percent of the sun's energy comes to us as infrared rays. The shortest of these are about 7.6×10^{-5} cm. or the limit of the so-called *near infrared rays*. The *middle infrared rays* extend from 2×10^{-3} cm. to 4×10^{-3} cm. Beyond this to 4×10^{-2} cm. is the limit of the *far infrared rays*. The hotter the source of these rays, the shorter the ray sent out by it. These short, near infrared rays are the easiest to detect and to use. Perhaps the most easily appreciated use of the infrared rays is in photography.

Uses of Infrared Rays

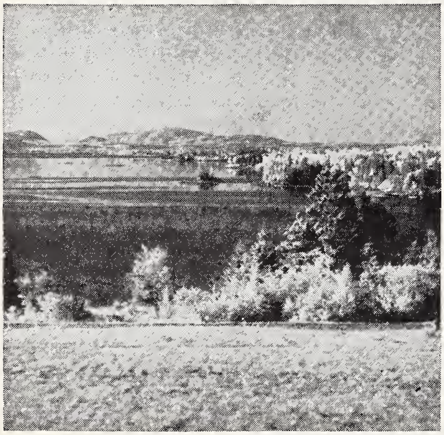
A hot object like an electric iron may be photographed in a dark room by the infrared rays it emits (Fig. 328). A relatively cool object such as a timid animal may be photographed at night in a forest by using an infrared flash bulb which he cannot see go off. Views of landscapes can be

EASTMAN KODAK LABORATORIES

328 This photograph was made in total darkness. The hot flatiron gave off infrared rays which registered on special film, making the photograph above.

taken with infrared rays by attaching a deep-red filter to the camera lens. This filter cuts out almost all the visible light rays while it allows the infrared rays to come through. The effects are dramatic (Fig. 329) and it is often possible to take a picture through haze. Haze is a mist caused by the scattering of light by very tiny bits of dust in the air.

Infrared rays come through haze (but not through fog) better than the rays of visible light because they are bigger in wave length than the size of the particles in the haze. Thus aerial views are often photographed on film that is sensitive to these rays. Color values are changed so that skies appear black and flesh tones appear thin. Infrared is not good for portraits but people can be photographed in the dark without their



PHOTOS BY HELEN FAYE

329 Two photographs of a Maine scene. *Above*, taken with normal film. *Below*, taken with a filter that allows only infrared rays to strike the film. Note the detail revealed in the distant mountains.

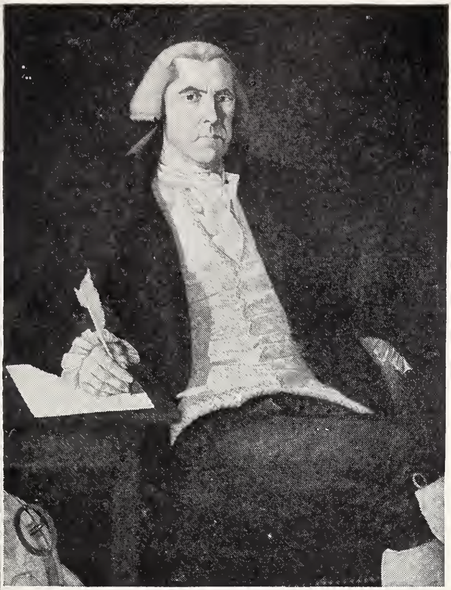
knowledge. This makes infrared photography valuable in detective work and in the protection of valuable property.

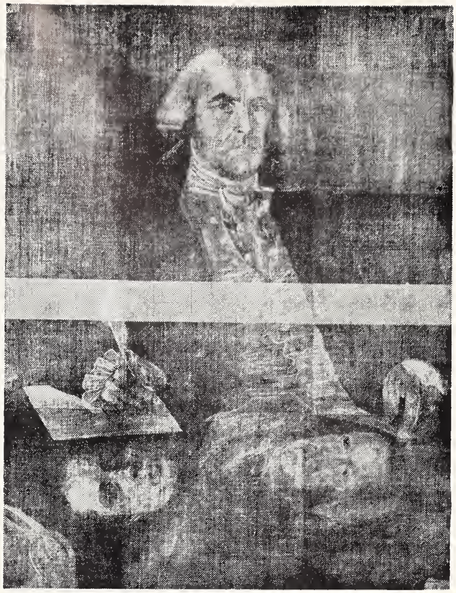
As you can guess from Fig. 330, infrared photography is also useful in crime detection by revealing hidden fingerprints or changes in documents. These things may not show up under ordinary light because they do not contrast with their background. But under infrared rays their presence is revealed because of differences in reflecting and absorbing these rays. These differences provide the needed contrast.

Works of art can be identified and faded maps or documents read by making photographs of them with infrared light. In medicine these rays are used to reveal certain disorders of the circulatory system, particularly in veins near the surface of the skin. They are also used in the diagnosis of certain eye disorders. A normal condition is contrasted with one suspected of being abnormal. If an abnormal condition exists, the differences show up under the infrared light.

An entirely different use of infrared rays in communication is found in the homing mechanism of the U.S. Navy's air-to-air guided missile called the "Sidewinder." Infrared rays given off by the heated part of the target, such as the engines of an airplane, communicate the target's location to the missile. As soon as the missile detects these rays, it adjusts its flight path to close in upon the target until it has been intercepted and destroyed.

One more use of infrared rays as a source of information should be mentioned. It has to do with Herschel's original discovery. You remember he put a thermometer bulb into the infrared part of a spectrum. The temperature of the mercury rose because the rays imparted heat energy to the molecules of mercury in the thermometer bulb. This made them move more rapidly and the total length of the column of mercury was





IN THE BROOKLYN MUSEUM COLLECTION, DICK S. RAMSEY FUND

330 Infrared photography reveals hidden paintings masked by the portrait on the left. Hidden masterpieces of art are sometimes discovered in this manner.

increased. You have seen this happen if you have ever watched a thermometer indicate a rising temperature. It has been discovered that when molecules are heated they vibrate in different ways depending upon the atomic structure of the molecules. The molecules of mercury do not vibrate the same way as the molecules of lead or iron. There are many chemical substances that are difficult to distinguish by ordinary chemical means. An invention called the *infrared spectrophotometer* helps chemists to distinguish these compounds. The vibrations of the molecules are studied while the substances are being heated by infrared rays. Although one of these instruments costs as much as several high-priced automobiles, it offers a reliable method of identification and it saves a great deal of time.

By now you have learned that communication has a very special meaning to a scientist. He uses a great many techniques unknown to the average person, to obtain and to use information. He often employs electronic messengers to do the job. Today many people use some of these same messengers to exchange or to broadcast ordinary messages. But there is nothing ordinary about the modern use of the longest electromagnetic waves known as hertzian waves. They were named in honor of the German scientist, Heinrich Hertz, who discovered them in 1886.

Hertzian Waves

The first point you will want to note about these waves is their long wave length. The shortest are about

1×10^{-2} cm. in length and the longest are about 3×10^{7} cm. The powers-of-ten notation we have been using is fine for comparing these waves with other types of electromagnetic waves. But it is easier to talk of these waves in standard units of the metric system. The shortest of these waves is about 0.1 millimeter in length and the longest is about 30,000 meters or 30 kilometers. That is over 18½ miles.

These waves are often described or identified by their frequencies instead of their wave lengths. The ordinary or standard broadcast band waves are from 10 to 30,000 kilocycles. If you have forgotten what this term means, refer back to p. 589. Ultra short waves are from 30 megacycles (that is, 30,000 kc.) to 300 mc. Hertzian waves up to 500,000 mc. are known as the microwaves. This band was the last to be investigated and to be put to practical use by scientists.

Within each of these broad bands of frequencies there are smaller bands or *channels* which have been set aside for special purposes. You are, no doubt, familiar with the term *channel*, for it is in popular use in television. Some of the other channels are devoted to FM radio broadcasting, to police calls, to military communication, to ship-to-ship messages, to ship-to-shore calls, to radar, to amateur broadcasting, to aviation, and to distress signals (Fig. 334). In Chapter 30 the special problems and techniques of using hertzian waves in radio and television will be discussed in detail.

You have now learned how seven kinds of electromagnetic waves are alike and how they differ. To help you keep the various kinds clear in your mind, refer to Table 15.

TABLE 15 Comparison of Electromagnetic Waves

Type of Wave	*Shortest*	*Longest*
Cosmic rays	5×10^{-14} cm.	5×10^{-13} cm.
Gamma rays	5×10^{-13} cm.	1×10^{-8} cm.
X rays	1×10^{-8} cm.	1×10^{-6} cm.
Ultraviolet	1×10^{-6} cm.	4×10^{-5} cm.
Visible light	4×10^{-5} cm.	7×10^{-5} cm.
Infrared rays	7×10^{-5} cm.	4×10^{-2} cm.
Hertzian waves	1×10^{-2} cm. (0.1 mm.)	3×10^{7} cm. (30,000 m.)

IF YOU ARE INTERESTED

Using the Powers-of-Ten Notation

As you have seen, the wave lengths and frequencies of electromagnetic waves may be written as powers of ten. This method is not only a kind of mathematical shorthand but it is also a short cut to use in making calculations with any very large or very small numbers. Here are two advantages of this system. First, to multiply numbers with powers-of-ten exponents, you merely add the exponents:

$$1 \times 10^{6} \text{ times } 1 \times 10^{4} = 1 \times 10^{6+4} = 1 \times 10^{10}$$

To divide you subtract the exponents:

$$1 \times 10^{6} \div 1 \times 10^{4} = 1 \times 10^{6-4} = 1 \times 10^{2}$$

To multiply 1×10^{-8} by 1×10^{5}, think $1 \times 10^{-8+5} = 1 \times 10^{-3}$. Of course, the digit before the "$\times$ 10" may be larger than 1. In that case, simply multiply these digits first, like this: to multiply 6×10^{-8} times 2×10^{5}, think $6 \times 2 = 12$; then think $10^{-8+5} = 10^{-3}$ and combine the answers thus: 12×10^{-3} or 1.2×10^{-2}.

Second, by writing numbers in powers-of-ten notation you can more easily compare things of different sizes. You can see at a glance that a wave length of 1×10^{-10} cm. is ten times longer than a wave length of 1×10^{-11} cm. And you can see at once that a wave with a frequency of 8×10^3 cycles has a frequency 4 times as high as a wave of 2×10^3 cycles.

You can use the powers-of-ten notation to compare any measurements, but the measurements must be stated in the same kind of units. You cannot compare measurements in feet with measurements in inches until you have changed the feet to inches or the inches to feet. And you cannot compare units in the English system with units in the metric system unless you change them first to their equivalent in the other system. Scientists prefer to use the metric system for measurement because units within that system can be changed to larger or smaller equivalents simply by moving the decimal point. In the English system this cannot be done.

Let us look at the metric system, which we have been using for measurements since Chapter 1. These measurements can be expressed in meters or in centimeters by using powers of ten, as shown in the table at the foot of the page.

Scientists use still smaller units of measurement in the metric system, but you will not need to use them this year. If you come upon them in any other books, a good dictionary will tell you enough about them so that you can fit them into the table. By looking at this table, you can see at once that a kilometer is 10^3 or 1,000 times larger than a meter and that a micron is 10^6 times smaller. (The *minus sign* ($-$) means smaller because it tells you the number is a fraction.) So if you are comparing a micron to a kilometer, the micron is 10^9 times smaller than a kilometer and a kilometer is 10^9 times larger than a micron.

Here is an example to show you how to make use of this information about the powers-of-ten notation in your further study of electromagnetic waves. Do you remember the equation $v = Lf$? You know that the velocity (v) of all electromagnetic waves is always the same, 186,000 miles per second. Let us change this value into the metric system. It is 3×10^8 meters per second. This means, then, that the wave length (L) times the frequency (f) of electromagnetic waves is always equal to 3×10^8 meters per second. If the length of a wave increases, what will happen to the frequency? Try stating

METRIC MEASUREMENT IN POWERS OF TEN

kilometer (km.) = 1,000 meters = 1×10^3 meters = 100,000 cm. = 1×10^5 cm.
meter (m.) = 100 cm. = 1×10^2 cm.
centimeter (cm.) = 0.01 m. = 1×10^{-2} m.
millimeter (mm.) = 0.001 m. = 1×10^{-3} m. = 0.1 cm. = 1×10^{-1} cm.
micron (μ) = 0.000001 m. = 1×10^{-6} m. = 0.0001 cm. = 1×10^{-4} cm.

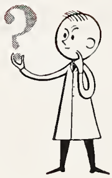
it in your own words. Now compare your statement with this one: Since v does not change, an increase in L must be matched by a decrease in f in the same proportion. This means that if a wave is 10 times longer than another wave, its frequency must be one-tenth the frequency of the shorter wave. On the other hand, if a wave is 10 times smaller than another wave, its frequency is 10 times greater.

If you understand this, check the facts in the accompanying table and see if you agree that they are correct.

For certain types of radio waves:

If the frequency (f) *is:*	*The wave length* (L) *is:*
1×10^4 cycles/sec.	3×10^4 meters
1×10^5 cycles/sec.	3×10^3 meters
1×10^6 cycles/sec.	3×10^2 meters
1×10^7 cycles/sec.	3×10^1 meters
1×10^8 cycles/sec.	3 meters

Multiply the first column by the second, remembering to add the exponents and to multiply the digits, and then combine the answers. Each example gives the same answer, 3×10^8 meters per second. As you can see, if the frequency increases 10 times (one power of ten), the wave length becomes one-tenth (one power of ten) shorter. In every case the product of the two numbers representing the values of L and f equals the speed of light, 3×10^8 cm. per second. And if you are sure you understand this, you are now ready to read some of the more advanced books on electromagnetic waves, such as: *Basic Physics* by Alexander Efron, John F. Rider, 116 W. 14th St., New York, 1957, Chapters 13, 18, 23, 24, and 41. In these chapters you will find an extension of the ideas you have learned in this chapter and those in Chapter 27.



LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meaning below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

wave length	fluorescent	far ultraviolet
frequency	powers-of-ten notation	phosphors
cycle	near infrared rays	phosphorescence
velocity	far infrared rays	Roentgen rays
kilocycle	channels	hertzian waves
megacycle	exponent	middle infrared rays
gamma rays	oscillate	infrared spectrophotometer
cosmic rays	near ultraviolet	fluorescence
	middle ultraviolet	

1. these are the longest of all of the electromagnetic waves
2. this word means speed
3. these glow under ultraviolet light
4. one complete wave
5. one thousand complete waves
6. the property of certain substances to glow longer than 10^{-8} seconds after an exciter has been turned off
7. the property of certain substances to glow less than 10^{-8} seconds after an exciter has been turned off
8. another word for substances with the property described in No. 7
9. the number of times per second that a wave cycle may be completed
10. a million complete waves
11. the distance from the crest of one wave to the crest of the next
12. the next shortest rays after X rays
13. the shortest of all rays
14. to move rapidly back and forth
15. a shorthand method of writing very large or very tiny numbers
16. the small number 8 in the figure 10^8
17. bands of electromagnetic waves, especially those used in broadcasting
18. the shortest ultraviolet waves
19. the longest ultraviolet waves
20. the rays next longer than those of red light
21. rays that overlap with hertzian waves
22. a device for identifying chemicals by causing their molecules to vibrate
23. X rays
24. rays that are filtered out by a good suntan cream
25. the middle range of rays used in the guiding of certain missiles to their targets

Test Yourself

In your notebook complete the following sentences with the correct word or phrase. DO NOT WRITE IN THIS BOOK.

1. The velocity of electromagnetic waves may be stated in round numbers as . . . miles per second, or as . . . centimeters per second.
2. The frequency of 30,000 kilocycles may also be stated as . . . megacycles.
3. The number 3×10^8 is . . . times as large as the number 3×10^6.
4. The number 3×10^8 is . . . times as large as the number 6×10^8.
5. The type of electromagnetic wave used in radio broadcasting is a . . . wave, named after its discoverer.
6. A common type of electric lamp that is coated on the inside with phosphors is known as a . . . lamp.
7. Infrared rays heat objects because they cause the molecules of these objects to . . . faster.
8. A clue to the discovery of . . . rays was the unexplained discharge of an electroscope.
9. The fogging of a completely covered photographic plate helped lead Roentgen to the discovery of . . . rays.
10. The upper layers of the earth's atmosphere filter out the . . . ultraviolet rays.

GOING FURTHER

In the Laboratory and Field

1. *Use a radiometer* to demonstrate the presence of heat rays in the infrared portion of the spectrum. A radiometer is a device with four tiny vanes that spin around under certain conditions.

2. *Infrared photography project* work may be done by a committee, each member of which has a camera to which an infrared filter may be attached. Take pictures of landscapes with and without a filter while using ordinary film in one camera and infrared film in another. Compare the results. Another member of the committee may take pictures indoors of hot objects such as an electric toaster or iron. A fourth student may also work indoors with an infrared filter over a photoflood or photoflash bulb. His job will be to show how hidden ink marks and fingerprints can be detected with infrared photography.

3. *Visit a radar installation*, which your teacher may be able to arrange for you through a telephone company, radio station, shipping center, or airport. Observe the apparatus used for sending and receiving the signals. Note particularly the way the radarscope works.

Put on Your Thinking Cap

1. Why is it more convenient to use the metric system than the English system for measurement of wave lengths of electromagnetic waves?

2. By what tests can you demonstrate that electromagnetic waves do exist?

3. If you have a light source which gives out both visible and invisible rays, what means can be used to cut down the range of the light waves so that a certain ray or color is fairly well eliminated?

A Bit of Research

You have decided to put your knowledge of ultraviolet rays to practical use in: (a) the designing of scenery and costumes for a science and art assembly program. Find out where paints and dyes affected by these rays may be bought and then experiment with them to create various effects, or (b) plan a trap for a "thief" by leaving some phosphor powder of the type used by the police in a place where it will get on his hands if he touches a certain object of value, or (c) using a phosphor powder and a source of ultraviolet light, demonstrate to a class how easy it is to spread "contamination." Information can be obtained from Science Materials Center, 59 Fourth Ave., New York 3, N.Y.

Careers for You

Have you ever thought of becoming a radiologist? These are members of the medical profession who make a specialty of employing X rays and other types of rays in ways that will prolong life or make living more comfortable. Investigate the qualifications, duties, and dangers as well as the rewards for this kind of work. Report your finding to the class.

Adding to Your Library

1. *Infra-red and Ultraviolet Photography*, Eastman Kodak Company, Rochester, N.Y. This 36-page data book will give you all the information you need to carry

out photography projects using infrared and ultraviolet rays.

2. *Electronics for Everyone* by Monroe Upton, a Signet Key Book, rev. edition, New American Library, New York, 1957. Here is a book which you should read between this chapter and the next one. It will give you much of the early history of radio and wireless.

3. *The Story of X-Rays*, a General Electric Co. bulletin of 36 pages, Schenectady, N.Y. It gives an interesting account of the history of X rays and their many uses. It is free.

CHAPTER 30

Sending Sound and Images Through the Air

No miracle, television. Television, like many other discoveries in science, is the result of slow, patient, hard work by many men and women. One result: another use of the discoveries of science for better living.

In 1872, an American dentist named Mahlon (MAY-lun) Loomis wrote an article titled "A Disturbance in the Electrical Equilibrium of the Atmosphere." The article describes an idea on which he got a patent that year. A few years later the idea became known as wireless telegraphy. Today we call it radio.

The telephone had not even been invented, and yet here was Loomis, who believed it would some day be possible to send and receive messages by setting up electrical waves in the air. He had none of the three things needed for this kind of communication — no transmitter, no receiver, and no electrical (actually, electromagnetic) waves to carry the message. But he had a good idea.

RADIO

Scientists were beginning to explore electromagnetic waves. One of the first to produce such waves was Heinrich Hertz (HYN-rikh·HEHRTS), a

German, who published his findings in 1887. The apparatus he used was so simple that it is not difficult for you to do what he did.

In Fig. 331, you see an apparatus that will produce hertzian (radio) waves. You need an electrical coil (called an induction coil), which makes sparks. You will also need a switch (key), four dry cells, and a spark gap joined to an antenna of some kind (the metal plates shown will do). Hertz received the spark made by the coil by using a heavy wire loop which he held near the transmitter. If you have no loop like this, you can hear the effect by turning on a radio nearby. The noises you will hear from the radio as sparks jump the spark gap are made by electrical waves sent by the spark. Do not keep up this experiment very long, or your neighbors who are trying to listen to programs will complain. Furthermore, it is against the law to broadcast any signal unless you have a license and obey certain rules.

Hertz was not interested in using these electrical waves to send messages. But Guglielmo Marconi (gool-YELL-moh·mahr-KOH-nee), a young Italian scientist, foresaw the great possibilities of using hertzian waves for sending messages long distances. In 1901, after many trials, he sent the first signal (the letter *s* · · ·) by radio across the Atlantic Ocean. Soon ships were using Marconi transmitters and receivers to exchange information with other ships and shore stations. The signal used was the noise of the spark sent as dots and dashes like a telegraph message. From this grew the broadcasting of music, baseball games, and mystery stories by radio and television. But first, to understand how this happened, there are some things you need to know about these waves.

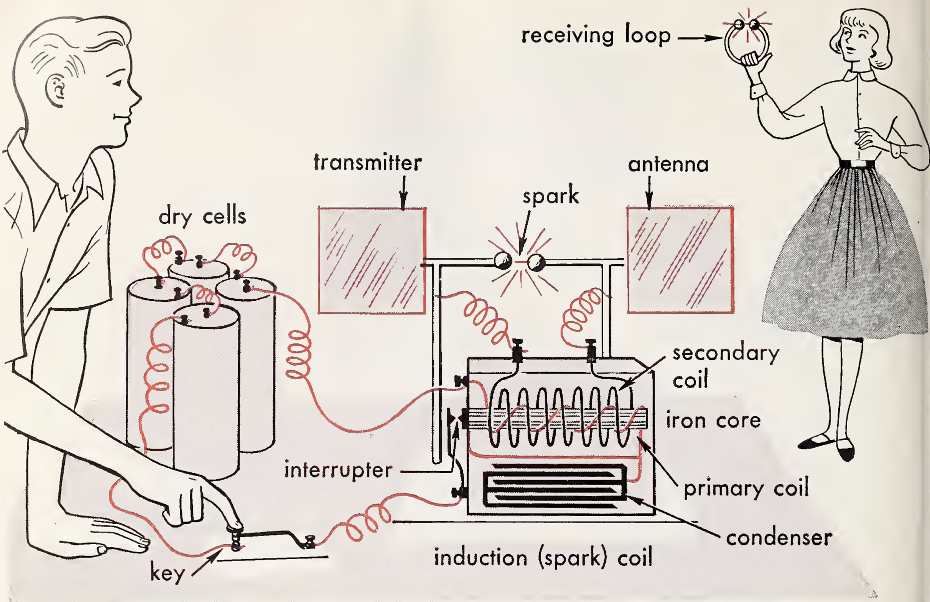
Producing Radio Waves

As you learned in Chapter 29, radio waves are like any other electromagnetic waves. They all travel at the same speed — the speed of light, which is an electromagnetic wave. Each type of wave has its own frequency, that is, the number of oscillations it makes per second. This number is thousands or even millions per second. What can we find that will oscillate or vibrate as fast as this?

In Chapter 26 you learned that the frequency of vibration of a sound increased when smaller vibrators were used; that is, the smaller the vibrating object, the faster it vibrated. Also, the frequency increased when the vibrators were more tightly held. Tightening a violin string is an illustration.

A frequency of 60 cycles (60 oscillations) per second for electricity can be made mechanically in a rapidly spinning generator. Sixty cycles is probably the frequency of electricity in your home. As you have learned (Fig. 331), such oscillations set up electromagnetic disturbances in the space around them; these are known as radio (hertzian) waves. The producer of such vibrations is called an *oscillator*. Of course, radio broadcasts are made in kilocycles, so 60 cycles is not practical for the purpose. A sparking vibrator can make a thousand oscillations per second.

To get frequencies greater than a thousand per second, something different is needed. A special type of tube, called a *vacuum tube*, was found



331 *Project:* To send a spark by radio waves (also called hertzian waves in honor of their discoverer), you may build an apparatus like this. Be sure the sending antenna is made of large metal plates and that the receiving loop is a heavy loop of copper. You will need to buy the spark coil.

to serve the purpose. With it, it is possible to get almost any desired frequency within the range of radio waves. Their action depends on a rapid back-and-forth flow of electrons. Electrons are light in weight, electrically charged, and therefore easily pulled back and forth. Also, they travel at high speeds.

But what controls the frequency of these waves? You know that two pieces of metal separated by an insulator can be used to store or hold an electrical charge. Such a device is called a *condenser* or *capacitor*. By long experimentation scientists discovered what happened when the charge on the condenser was drawn off. If we connect the two metallic plates with a wire, we get all of the charge in a very short time and see a spark (Fig. 331). If, however, the current is made to go through an electrical resistance, the charge comes off more slowly. Each arrangement of capacity for the condenser and resistance has its own rate of electron discharge.

Now let us look at the tuning device in your radio. You know that the frequency band on which a radio station can broadcast is set within a narrow range or band by government regulation and that you get the station you wish to listen to at the same point on your dial each time you listen. How is it that you get just the station you want to listen to? If you can get two tuning forks of just the same frequency, you will find that one reinforces the other, making the sound seem louder. Or tighten

two violin strings to the same length and tension next to each other. If you now pluck one string, the other will start to vibrate. We say that the tuning forks and the strings are in *resonance*. In just the same way, we tune our receiving set so that it is in resonance with the frequency of the station we are listening to. To select the frequency to which the receiving set is resonant, we may change either the resistance or the capacity. We tune most radios by changing the capacity of the condenser because this is easier and uses a part that does not wear out readily.

If a large variety of frequencies is fed into a radio-receiving circuit, only certain frequencies will be let through. Such a circuit is really a *filter* of frequencies, since only those frequencies to which the set is in resonance will be let through.

Thus far we have mentioned only resistance and capacity. A coil of wire has similar properties and is also often used with resistances and condensers. Coil, resistance, and condenser — these are three of the major parts of any radio circuit.[1]

To summarize what we have learned so far, in order to generate a radio wave a rapidly changing current of electrons is set up in a special vacuum tube. This current is then filtered — or controlled in frequency — by being passed through other parts of the broadcasting circuit. Finally, a strong current of the frequency assigned to the broadcasting station is permitted to flow between the antenna and the ground. As the current sloshes back and forth, electromagnetic waves are formed around the antenna. These spread out with the speed of light in all directions to be picked up by the antenna of any radio receiver. However, note that so far we have been discussing only the sending of the wave of the frequency assigned to the broadcasting station. Presently we will note how this wave carries voices and music.

Receiving the Signal

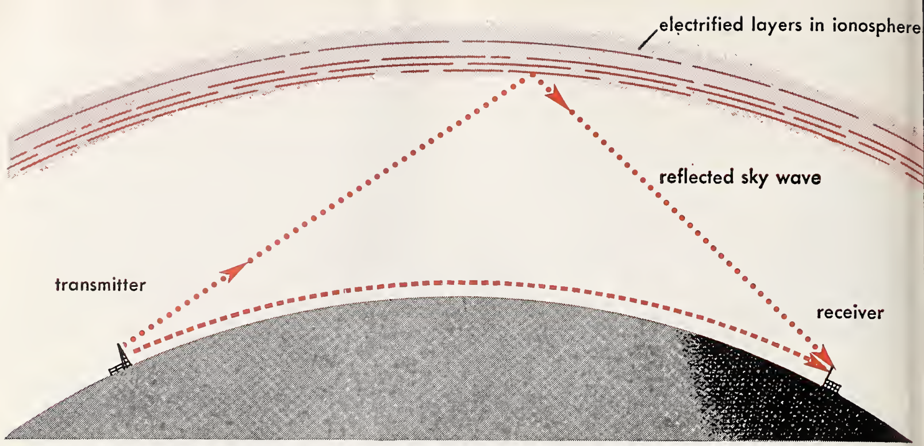
Only a very tiny part of the broadcast signal will flow past your radio antenna. However, even this weak signal causes some of the electrons in the antenna to surge back and forth. The current they make is then carried through an amplifying circuit in your set so that a strong signal is fed to your earphones or loudspeaker. In many ways your receiver works like a relay in which a weak incoming signal controls a new strong signal that copies the original signal.

If there were only one radio transmitter in the world, each receiver could be built to pick up only that one frequency. But there are many signals coming to your antenna, all of them causing electrons to flow back and forth at the frequency they were broadcast. Therefore, you need a carefully made tuner that will allow you to pick out the one station you wish. If your tuner does not filter out very well the signals you wish to listen to, you are likely to get the signals from two or more stations at one time. This may happen if you make the simple radio receiver shown at the end of the chapter.

Tubes and Transistors

There is more than this, however, to the design of a radio. The incom-

[1] If you wish to know more of the details of radio circuits, consult the readings on p. 624.



332 Radio signals travel out in all directions from the transmitter. Those near the earth are bent. If conditions in the upper layer of the atmosphere are right, a radio set may sometimes receive reflected signals from distant stations as well as direct signals from nearer stations.

ing signal is an alternating current. But earphones and loudspeakers react only to changes in the strength of a direct current. In the receiving set we need a valve or gate to cut out the backward flow of alternating current and let only the forward flow go through. This is what certain types of radio (vacuum) tubes, crystals, and transistors do. They are "one-way gates." Because an electrical current can go through them in only one direction, they can change an alternating current into a direct current. Any part that will do this is called a *detector*.

Amplifiers

A tube and a transistor, but not a crystal, can increase or amplify the strength of a signal by as much as a hundred times. With several tubes in a set a very weak signal can be made strong enough to operate a loudspeaker. Since a crystal set, like that shown on p. 623, has no amplifier, you need to increase the number of signals you collect. This can be done by using a long antenna. Even then you will be able to hear only nearby stations that send out strong signals.

How Signals Travel

You have seen how a radio station sends out powerful electromagnetic waves. But how do they get to your antenna? All such signals travel with the speed of light. Do they, like light, move only in straight lines? When the first wireless experiments were made, people expected that all such signals would travel like light. But to their surprise, they discovered that radio signals would bend a little around the curvature of the earth and could be received at places from which the transmitter could not be seen.

To their amazement they also received signals from stations many hundreds of miles away. Apparently the signals not only moved over the earth but also followed some other path. Simultaneously, an English-

man named Heaviside and an American named Kennelly concluded that an electrical reflecting layer must exist high in the atmosphere. This reflecting layer, or "radio roof" (Fig. 332), is now known to be quite complex and is called the *ionosphere.* It consists of electrified layers high in the thin upper atmosphere. Signals reflected from the ionosphere are known as *sky waves.* They fade when changes occur in the reflecting layers. These changes often happen when great flares or storms on the sun send out extra amounts of ultraviolet light that electrifies our upper atmosphere.

Getting the Message

With the simplest type of radio transmitters, all we could send would be dots and dashes by turning the signal on or off for various lengths of time. This was wireless telegraphy. For many years radio signals were used in just that way. But later discoveries showed how other types of communication, like voices or music, could be sent by modifying the basic or *carrier wave.* This is the information which we want. The carrier wave is necessary to get the information to our receivers, but there only the extra communication on the carrier wave is amplified. In a way the carrier wave is like an airplane carrying a letter. At the other end we get the information in the letter, but are not much interested in the necessary airplane that did the carrying.

A radio operates much like a telephone. In a telephone we modify, or modulate, an electric current by our voice. In a radio we also modify the carrier wave by our voice or by music. What you receive is a *modulated carrier wave* from which your set picks off the *modulations* and changes them back into sound waves. Such modifications are now made in two ways.

AM — Amplitude Modulation

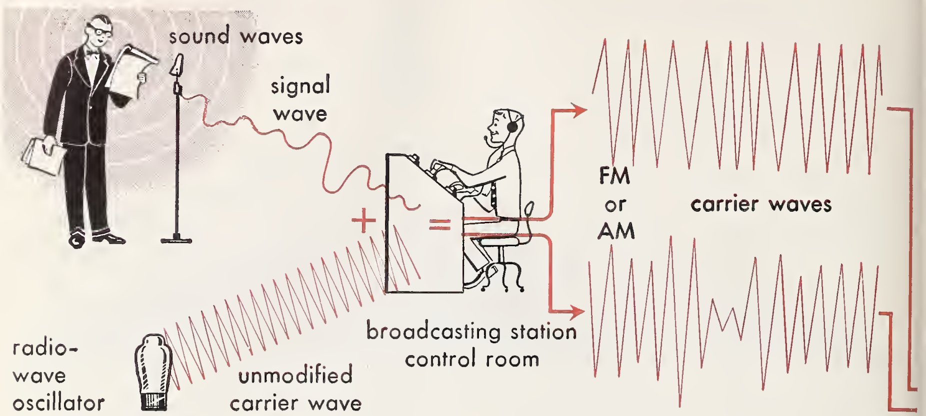
The first and simplest kind of modification is known as *amplitude modulation*, or AM. In this method the strength of the carrier wave is changed by the modulating voice or music. The changes in the signal strength carry the important communications. Unfortunately, static signals from thunder storms or electrical equipment also change the signal strength, so we may hear a message mixed with static crackles and hisses.

FM — Frequency Modulation

About 1935 the possibilities of modifying or modulating the carrier wave in another way were usefully developed. The result is *frequency modulation*, or FM. With FM the carrier wave from the transmitter is changed in frequency by the added voice signal. Changes in signal strength are not important. By frequency modulation most of the effects of static are avoided and FM programs are more pleasant to hear. For high-quality sound production you still need as good a loudspeaker as you would use for high-fidelity record playing.

Bands and Channels

The first wireless sets used a spark or vibrating reed to produce an alternating current. Such vibrators could oscillate from only a few hundred up to about a thousand times a second. The radio frequencies they



333 Radio broadcasts begin when a signal takes a ride on a carrier wave. The signal is any sound the broadcaster makes. The carrier wave is a radio wave made by a device called an oscillator. When the sound enters the microphone, it becomes an electrical signal in the form of an irregular wave. In the control room, this signal wave is put aboard the carrier wave,

produced were around one kilocycle (one thousand cycles). However, Lee De Forest discovered that a vacuum tube itself could be made to create a changing or oscillating current at higher frequencies. The first broadcasting stations operated at about a million cycles per second — one megacycle. As a result, the frequencies between 550 and 1,600 kilocycles were reserved as the broadcast *band.*

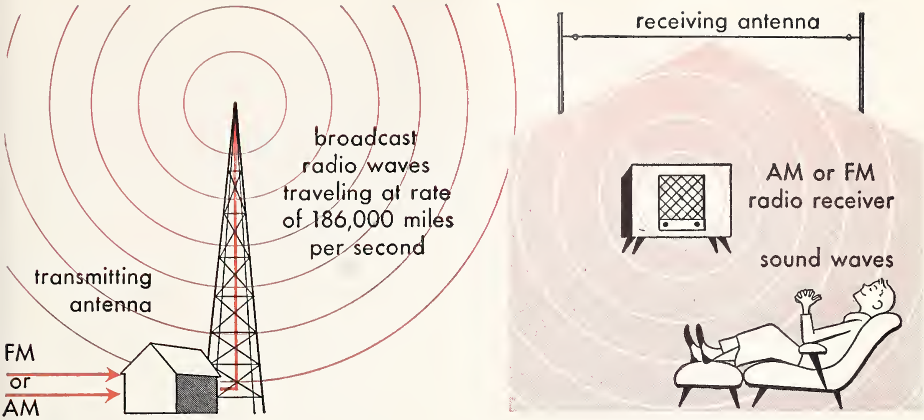
Frequency-modulated stations require a wider range of frequency for their transmissions. By the time FM was developed many special services were using radio signals and had been assigned channels near the broadcast band. FM stations were therefore assigned frequencies around 100 megacycles — between 88 and 106 megacycles.

These high FM frequencies behave more like light waves than do lower frequencies. The coverage or reception of FM signals is therefore limited to almost the line-of-sight. On the earth's surface this rarely exceeds about 75 miles. For greatest coverage transmitters are put on high buildings or mountains. As these high frequencies are not usually reflected by the "radio roof," they seldom have sky waves to be received at long distances. The same conditions apply to television stations which also operate on high frequencies.

As wireless and radio developed, certain bands of frequencies were given names, as Fig. 334 shows. These band names are often useful to describe where, among all the frequencies, a certain station is located.

Channels and Governmental Control

If everyone broadcast on any frequency he chose, you can imagine the confusion that would result. To prevent this, the government established in 1927 the Federal Communications Commission, or FCC, to allocate the



which is then changed in one of two ways — AM or FM. As you can see, AM means that the height or amplitude of the carrier waves has been changed. FM means that the spacing between the waves, or their frequency, has been changed. When tuned in, these radio waves are changed back to sound waves by the receiver.

bands for various purposes and to issue licenses for specific frequencies. Since there is a limit to the number of radio channels, and there are even fewer television channels, the competition for them is often intense.

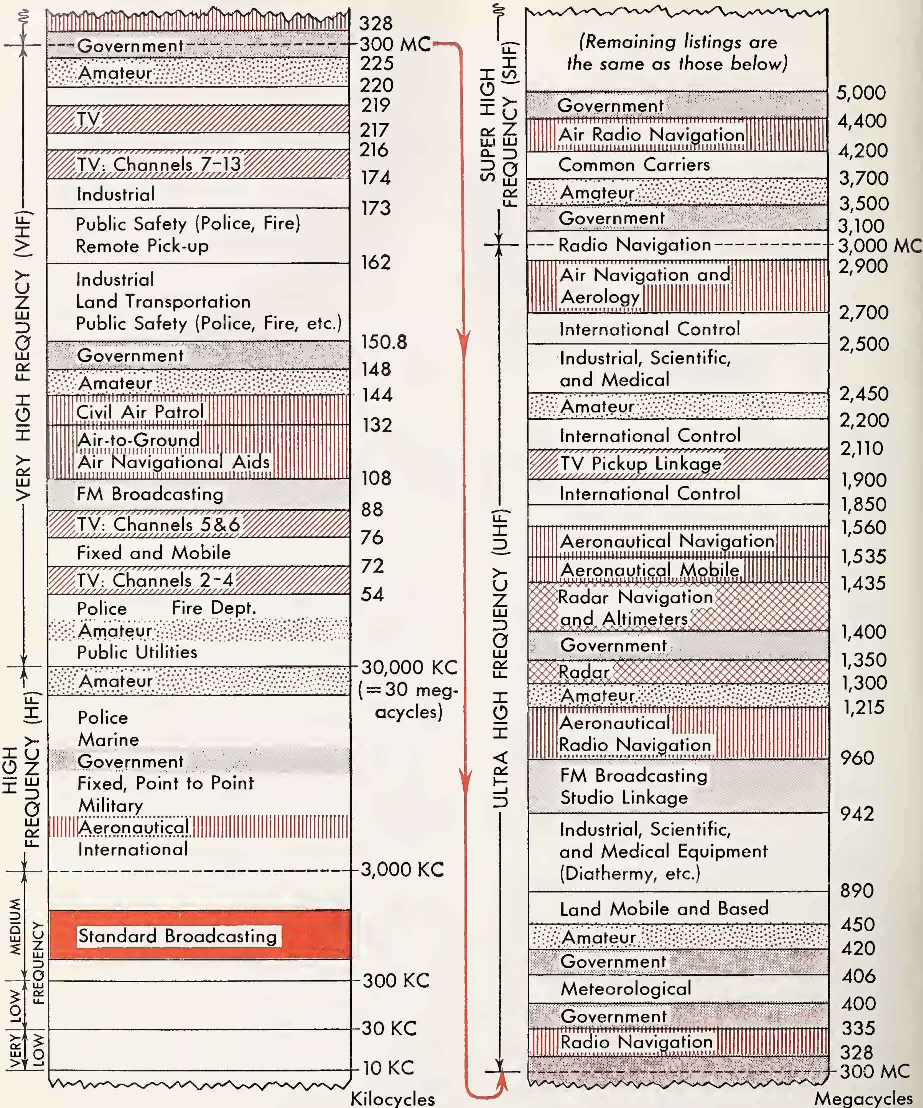
The number of channels is limited because the signals from each station go out on not just a single frequency, but on a narrow band of frequencies. Actually, the broader the band of transmissions, the less distortion there is in the sound when reproduced. But a reasonable limit must be set for the band width. For AM stations a transmission channel is 10 kilocycles wide. For FM stations it must be considerably wider, 200 kilocycles. TV stations each require a channel 6 megacycles wide! No wonder the number of TV stations is limited.

Since the low-frequency broadcast band signals can bounce around the world, even international agreement on frequency and power assignments has become necessary. The group that makes such decisions is known as the International Telecommunications Conference.

As you know, certain bands are reserved in the United States for the use of police, for ships, for ship-to-shore telephones, for amateurs, for the military services, for aircraft contact and control, and for many other important services. Perhaps the most important of all channels is that at 500 kc.; this is the international distress frequency. It is used only when emergency help is needed by ships or aircraft. At many rescue and emergency stations a receiver tuned to this frequency is always "on." There is a severe penalty for broadcasting on an unlicensed channel and especially for intruding upon the 500 kc. distress channel.

The first radio, or electromagnetic, signals sent by Hertz nearly a hundred years ago opened up a great field in which many people find jobs in designing, building, or repairing

FREQUENCY BANDS FOR ELECTRONIC COMMUNICATION



(COURTESY OF THE FEDERAL COMMUNICATIONS COMMISSION)

334 To prevent confusion in communication by means of electromagnetic waves, the Federal Communications Commission permits transmitters to broadcast in channels between only certain wave frequencies. These channels, or bands, are assigned for the purposes shown in the chart. To follow the frequency bands from lowest to the highest frequency, start at the bottom of the first column, read up, and follow the colored arrow to the second column.

equipment or planning and presenting programs. An even newer and more costly member of this growing family is television. Another form of man-made electromagnetic waves is radar, which has great importance for military defense and civilian safety.

TELEVISION

Television is an invention that uses many ideas and objects you have met before in the explanation of motion pictures, radio, and photography. These include the use and control of light, persistence of vision, the photoelectric cell, modification of carrier waves, and the growing knowledge of the use of vacuum tubes, such as those used in radio receivers. All these are used to broadcast and to reproduce television images. The television channels are 44 to 88 and 174 to 216 megacycles (Fig. 334).

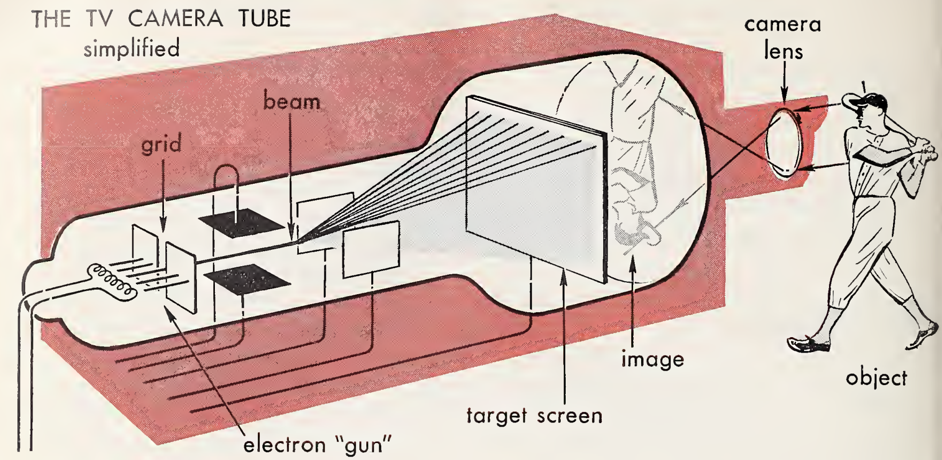
Broadcasting Images

Let us start by going to a ball game which will be televised. We know the cameraman, so he allows you to peep into the viewer for a few moments before the game starts. What you see is like what you would see if you looked into a good camera with a ground-glass viewer. Home plate is in fine, sharp focus. But as you move the camera toward the right field foul line the image becomes blurred. You then focus the lens. To bring in a wider view, or to get a close-up of the pitcher, you change lenses as you might with a camera. So far, television seems to be just like photography.

The next step is to change the image or picture into a current of electricity. Our TV camera has in it a special kind of tube (Fig. 336). At one end this camera tube has a thin screen which is a kind of photoelectric cell. The image of the scene

335 Action in a TV studio goes on with split-second timing. Notice how the floor manager gives directions with hand signals. Note, too, that he and the cameraman are wearing earphones. They receive their orders by telephone from the director's booth outside the studio.

CBS-TV



336 A special tube is the heart of a television camera. It is able to send out clear image "signals" to be picked up by a television set. Its main parts are a screen and a "gun" whose beam of electrons moves back and forth 525 times per picture, scanning 30 pictures per second.

in the ball park (with its light and dark parts) is focused on this screen. The light parts of the scene release *more* electrons from the screen; the *darker* parts release *fewer* electrons. These released electrons are pulled away by positively charged wires nearby. You will remember that an electron has a negative charge and that unlike charges are attracted. This release of electrons leaves the back of the screen with a strong positive charge wherever the original picture image was light (more electrons released). A weak positive charge is left wherever the picture image was dark (fewer electrons released).

An *electron gun* [1] at the other end of the tube sends out a narrow beam of electrons. When no image is on the target screen, the electrons are all pulled back by a strong positive charge within the tube. If a bright light made a positive spot on the target, some electrons move to it. Then the returning stream is weaker. The electron beam moves across the target screen along 525 lines and can change in intensity about 600 times per line. Each picture, therefore, is made up of over 300,000 dots (525×600). And 30 pictures are made each second! Because of persistence of vision (p. 575), we see one continuous moving picture.

[1] The electron gun is given this name here because it shoots out a stream of electrons. Technically, it is sometimes called a *cathode* (KATH-ohd)-*ray tube* because the electrons have their source at a hot piece of wire called a cathode.

Reproducing the Picture

The transmitted signal contains all this information in proper order and your receiver must be tuned to receive the signal and make a picture for you. In addition, special signals are sent to indicate to your receiver when each new picture is about to begin so that the receiver can lock on at the proper part of the sequence.

Many radio vacuum tubes and

much wiring are needed to make this image in your picture tube. Only the technical expert who builds or repairs television receivers needs to be concerned about the details. But two details do concern everyone. Because high voltages are used, there is the chance of getting a dangerous shock in handling the mechanism inside a television receiver. "Keep your hands out" is a good rule to obey. Remember also that a television picture tube has a high vacuum. If mishandled it may break violently, causing injury from flying glass coated with poisonous chemicals.

The picture tube in your television set is a type of radio tube, a cathode-ray tube (see footnote on p. 616), which shoots out a stream of electrons in the direction of a glass screen. This screen is coated on the inside with phosphors that glow when electrons hit them. There is little difference between the substance in the cathode-ray tube and the chemicals used to coat the inside of the ordinary fluorescent light tubes that may light your kitchen. But the source of the electrons is very different. The beam in the picture tube is controlled by several devices placed along its path. As the trigger signal from the television station is received, the beam scans the screen in the same way and at the same speed as the beam in the camera tube. Your tube's beam changes in its strength, too, and wherever it is more intense the chemicals glow more brightly. Thus we see an exact duplicate of the image which the cameraman sees in his view finder, except for one important detail. Your picture is black, gray, and white, but the original is in natural color. You can also have color television, but at a higher cost.

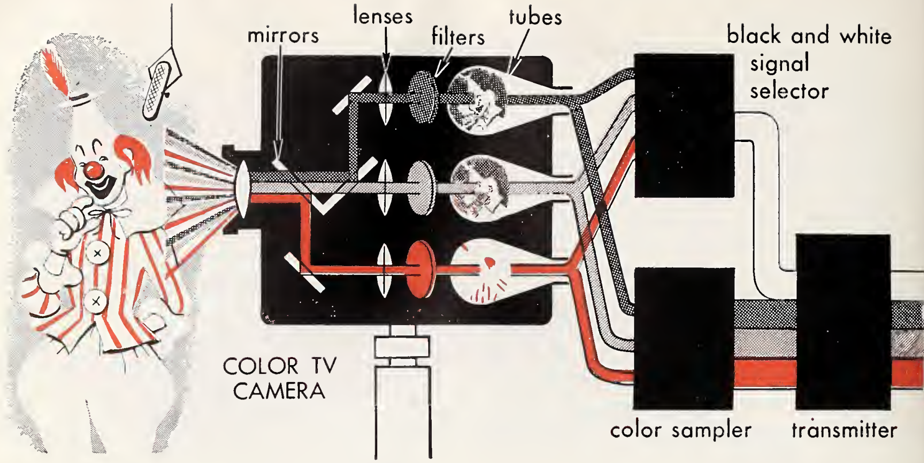
Color Television

The addition of color to television was a difficult technical achievement. The problems that had to be overcome began with the need for sending even more information. All scenes in color must be broken up into three parts: a red picture, a blue picture, and a green picture. We might use three television cameras, but this is not practical for many reasons. So one camera has to do the work of three. Figure 337 shows you how the light entering the lens of a color camera is divided into three parts.

Color receivers use a picture tube that is made with three electron guns, instead of one, and its screen is coated with three different kinds of glowing chemicals. One dot glows red, another blue, and the third green. They are grouped in little clusters — about 600,000 of them. The beam that carries the blue signals hits only the blue dots; the other beams of electrons likewise make only their own dots glow. Sometimes two of the dots glow, giving another color; for example, if red and blue dots glow together, the color we see is purple. The dots are so close together that, if the original object is white, all three dots at that point glow and give a white light on your picture tube.

TELEVISION'S COUSINS RADAR AND GCA

As you learned earlier, nearly everything you see is by means of reflected light. But our eyes are sensitive to only one little part of the total range of electromagnetic waves. Can we get echoes from re-



337 One color television camera has to do the work of three ordinary television cameras. It separates the incoming rays of light into three colors — red, green, and blue. An image in each color is translated into an electrical signal. Then the signals are added together to make

flected radio waves? Yes, the "ghost" images you sometimes get on a television screen are weak echoes that are reflected from some nearby object. They travel a bit farther than the strong beam and arrive late to show as a weak image to the right on your screen.

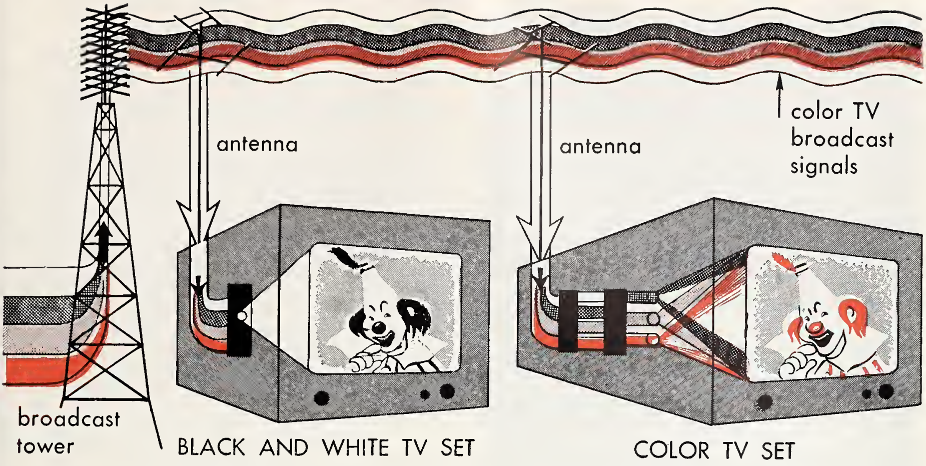
Perhaps you have even seen the echoes of an airplane on your television set. When a plane is nearby, the short waves from the transmitter may be reflected by the metallic plane and arrive at your antenna late. Sometimes these cause a streakiness in the picture that changes as the plane moves.

Electronic Echoes

The possibilities of detecting objects — especially good conductors like metal — by radio became important only when engineers learned how to make ultra-short radio waves only a few centimeters long. As Fig. 334 shows, the waves used for *radar* are usually less than 10 centimeters, or about 4 inches, long. Where longer waves will flow around a smallish object and give no strong echo, these shorter waves are bounced back. Their echo is very weak, and strong amplifiers are needed to pick them up, so a radar set is complicated.

But just to get echoes would be of little value. What we need is both the direction and distance of the object, generally called the "target." We can get the directions by sending the original signals in a narrow beam like that of a flashlight. Radar sets, therefore, use large mirrors to focus the signal into a beam. The mirror can be turned so that the beam sweeps over the entire sky.

The echoes from a radar set are displayed on a large cathode-ray tube much like a television tube.



a fourth signal, which will produce only a black and white picture in regular tubes. For pictures in color, a three-color tube is needed. This tube blends the three color signals into one true full-color picture.

While many different types of display are possible, that used most often is like a map. The transmitter is at the center of the picture. As the mirror turns, the direction of the electron stream in the display tube turns also. So an echo appears as a "blip," a spot of light, in the same direction as the antenna was turned. For example, if the mirror is facing east, the blip will be to the right of center on the screen. It will also appear near or far from the center depending on the distance of the target from the mirror.

But radar sets have other differences from simple radio or television sets which send out continuous signals. Radar sets send out a series of strong signals, called *pulses*, separated by a quiet time during which the equipment builds up the energy for the next pulse and receives the returning echoes. As many as a thousand pulses per second may be sent out. These travel at the speed of light, 186,000 miles per second. In a thousandth of a second they would go 186 miles, or have hit a target at half that distance, 93 miles, and returned before the next pulse was sent out.

Direction and Distance

As you may have guessed, the distance or range of a target is determined by the time needed for the signals to go out and echo back. This range is also shown on the display tube by the distance of the "blip" from the center of the tube. Fig. 338 shows a typical image on a radar set. The word radar is made up from *RA*dio *D*etection *A*nd *R*anging, R-A-D-A-R.

Radar has many uses. With it we can detect airplanes or ships. In wartime this may be very important. But also in peacetime, ships and planes can locate each other in

EWING GALLOWAY

338 A radar operator scans a typical image on a radar screen. From numbers on the outside circle and from the location of the dots of light, he can identify objects and find their distance and direction from his own location.

fog and avoid collisions. Also ships and planes can detect land areas, mountains, icebergs, and many other hazards. At night ships can locate buoys a mile or two away and steam up a channel as though it were a sunny day. Also, some of the radar waves are echoed back by water droplets in clouds. From such signals aircraft pilots can "see" clouds and storms ahead and avoid them.

GCA — Landing Aircraft

Ground-controlled approach for aircraft is another use for radar. From a strong radar set at the airport all the planes around it can be spotted and followed. If the weather is poor, the planes can be sent to different altitudes or areas to lessen the chances of collision while they await their turn to land.

Then, even when the pilot can see only a short distance ahead, skilled operators at the radar station can, by radio communication, "talk" him onto the runway. Sometime earlier, on a bright day, a skilled pilot landed an aircraft of the same type. A record was made of just how the plane moved in distance and direction. This is the model to be used when the weather is poor. Then the actual path of the incoming plane is compared to the model and the pilot is told whether he is to the left or right of the landing path and whether he is too high or too low. Thousands of landings have been made with this "talk down" or ground-controlled-approach system. Sometimes it is the only way by which a plane can be landed when the landing is important.

Our Shrinking World

Of course, you have listened to radio and viewed television programs which have made you aware of these as important means of communication. You know how they bring the outside world to your home and let you know about world events the minute they happen. These means of speedier communication make travel safer, and they help our governments do their work efficiently. The telephone helps you order food and household goods more quickly, visit with your friends more often, and get help much faster when you need it.

In George Washington's day, a journey of 60 miles took an entire day. Today within a minute you can speak to someone 60 or 6,000 miles away. Wire and wireless communication have made this a small world indeed. Faraway peoples have become your neighbors through improved means of communication.

Will the universe shrink, too? It seems possible that voyages will be made to the moon and to other planets within your lifetime — perhaps before 1965. Electronic messengers will be used to guide the space rockets, and radio, television, and other cousins yet to be developed will bring back information that will be useful in science and in increasing our knowledge of the world we live in. You live in an age in which the science of electronics will help to shrink our universe by speeding communication between people and things over great distances. Watch for new developments.

LOOKING BACK

Tool Words

Here are the key words to the big ideas in this chapter. In your notebook, match these words with their meanings below by writing the correct meaning after each word. DO NOT MARK THIS BOOK.

electron gun	band width	modulated current
tuning	detector	antenna
radar	sky wave	carrier wave
filter	ionosphere	pulse
oscillator		

1. a radio signal bounced back to the earth by the "radio roof," or ionosphere
2. a combination of radio parts that allows only certain frequencies to pass
3. a special wire or wires used for receiving radio waves
4. a radio wave that carries a signal from the antenna of the transmitter to the antenna of the receiver
5. an electric current that has been changed by the addition of a second current
6. a tube, crystal, or transistor that allows electrical current to flow in only one direction
7. the adjustment of a radio circuit to the frequency of a desired signal
8. the range of frequencies required for a radio transmission
9. anything that vibrates or sends out a wave such as a radio wave
10. the part of a cathode ray tube that forms and aims the electron stream
11. radio detection and ranging apparatus
12. an electrified layer in the upper atmosphere
13. a short, strong burst or radio signal

Test Yourself

1. Radar means . . . .
2. The spots on a radar screen are caused by the . . . of the radar beam.
3. Among the peacetime uses of radar are: (1), (2), (3), (4).
4. The first radio signals were made by the . . . sent out from an induction coil.
5. The first wireless signal was sent across the Atlantic Ocean in . . . .
6. A radio transmitter sending out waves that oscillate 1,200,000 times per second is said to be broadcasting at . . . kilocycles.
7. To change an oscillating radio wave into the kind of current that will operate a loudspeaker, we must pass it through a device called a . . . .
8. A device in which we can quickly store electrical charges is called a . . . , or a . . . .
9. To select just one frequency of waves out of many in a radio set, we pass the waves through a device called a . . . .
10. A radio wave can be amplified by two types of devices called . . . and . . . .
11. Microwaves have wave lengths of a few . . . .
12. The coverage of an FM station is limited because . . . .
13. In the United States control of the use of radio channels is done by the . . . .
14. Two dangers of handling a TV set are caused by . . . and . . . .

GOING FURTHER

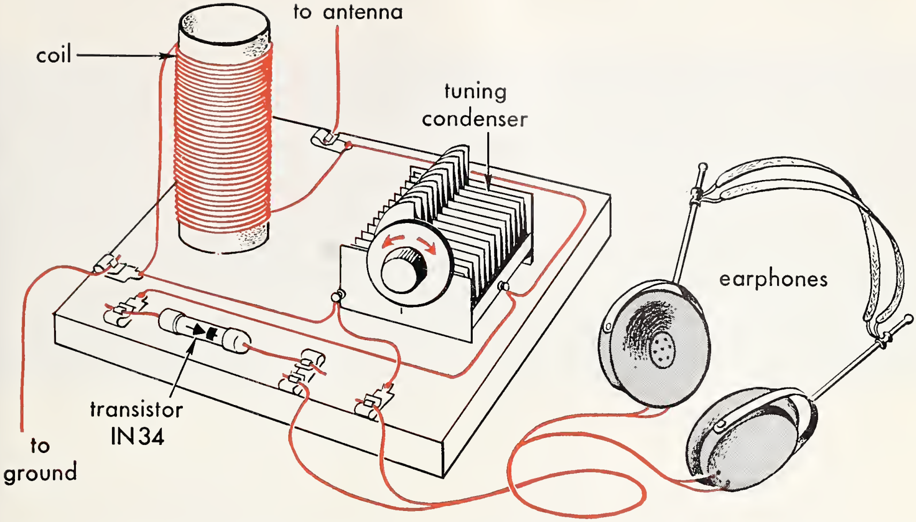
In the Laboratory and Field

1. *Making a crystal radio.* The first reference book in "Adding to Your Library" contains directions for making a "foxhole" radio receiver. If you make one, be sure to use a long antenna and also a connection to the ground. But we think you will get much better results if you build the transistor receiver shown in Fig. 339. You will also get much better results if you solder all your connections. Do not depend upon winding wires around a nail or other wires for good connections. At least put the wires between two washers and fasten the washers to a board with a roundhead screw.

2. *Making a vacuum-tube radio.* Your best chance of success, if you are a beginner in radio, is to make a simple vacuum-tube receiver. You can buy a kit with all the parts you need and complete directions for putting the parts together. Your radio dealer will probably be glad to give you some help or advice with it, and he will be able to get a kit for you, but first ask your teacher. He may have all the needed parts in his supply closet.

3. Visit a radio or television station. Find out about how the station was built, what it cost, what it costs to operate, how many people are employed, and what they do. Also, inquire about the license for the station and what must be done to keep the license. Ask about the power used to operate the station and what part is sent out as signal. Find or plot the locations in the nearby area in which the station's signal is well received.

4. Visit an airport, after obtaining permission, and observe the many ways in which radio and radar signals are used in air traffic control.



339 This simple radio receiver uses a germanium (jer-MAY-nee-um) diode instead of the galena crystal and "cat whisker" found in some crystal sets. Be sure to use a 50- to 75-foot aerial and a good connection to the ground. To tune in a station, turn the knob of the tuning condenser slowly. Now examine your own radio. What do you think is behind the knob you use to tune your radio?

5. Find out how astronomers use radar effects to study shooting stars. Also, look up the new field of "radio astronomy" to discover what can be learned about the stars and interstellar gas from the radio signals they send out.

Put on Your Thinking Cap

1. If it is possible now to send radio messages across the Atlantic Ocean, why is a transatlantic telephone cable also useful?
2. Why is it necessary for the Federal Communications Commission to regulate and license those who wish to make radio broadcasts?
3. Why would anyone want to send radar signals to the moon or to an earth-satellite? What range of frequencies in the electromagnetic waves would you have to use?

Adding to Your Library

1. *All About Radio and Television* by Jack Gould, Random, 1953. This book is a simple and accurate introduction to the subject of radio and television. It is well illustrated and has directions for building a "foxhole" radio receiver.
2. *Elements of Radio* by Abraham Marcus, 3rd edition, Prentice-Hall, 1953. For beginners who want to go more deeply into the subject, this is a clearly written book which will help you build various types of radio receivers.
3. *The Radio Amateur's Handbook* and *A Course in Radio Fundamentals*, published by the American Radio Relay League, Inc., 38 La Salle Road, West Hartford, Conn. These are standard works which give exact facts useful to those who want to make radio a hobby.
4. *The Boys' Second Book of Radio and*

Electronics by Alfred Morgan, Scribner, 1957.

5. *The Real Book of Electronics* by Edward Stoddard, Doubleday, 1956.

6. *There's Adventure in Electronics* by Julian May, Popular Mechanics, 1957. A young boy finds adventure and perhaps a career in the exciting world of electronics.

7. *Television and Radio Program and Commercial Announcing as a Career*, Institute for Research, Chicago, 1958. A pamphlet.

8. *Television Story* (rev. edition) by John J. Floherty, Lippincott, Philadelphia, 1957.

9. *Television Works Like This* by Jeanne Bendick, McGraw, 1954. This revised edition of this book is fun and up to date.

Careers for You

There is no wider field for career hunters than in communications. If radio appeals to you, the best way to begin is by earning your amateur's (ham) license. Write to the American Radio Relay League, 38 La Salle Road, West Hartford, Conn., for their booklets *How to Become a Radio Amateur*, *Learning the Radiotelegraph Code*, and *Radio Amateur License Manual*. For the information on other careers in the communication field, speak to your guidance teacher or to a friend in the business.

Projects in Sky Watching

Radio astronomy, earth satellites, and rocket explorations of space have opened to the astronomer a great new field of study, requiring new instruments and raising new problems. As a result, there is a need for more trained astronomers who can use these new tools on the new problems.

As a hobby, astronomy is most rewarding. You always have the heavens above as a laboratory, you need very little equipment to get started, and you can do it on your own in your own time. Furthermore, it gives you an opportunity to be out-of-doors in the fresh air, although it may steal away a bit of sleep occasionally.

Astronomy provides opportunities for people with quite different interests and with different abilities. If you like to work with your hands, you may be able to design and build instruments and equipment which are the envy of experts. If you are a radio "ham," you can study the heavens by means of radio waves given out by different stars, or you can design electronic equipment to aid the eye or to make more rapid recording of observations. Or you can hunt for comets and new stars, called *novae*. In the sky there are many stars that fade and then become brighter at regular intervals. Many sky watchers follow these variable stars and report their observations to the professional astronomers. And many people now watch for satellites, locating their position against the star map of the heavens. There is a place in astronomy for all skills and interests. It is a hobby you never outgrow.

If an interest started now becomes a career, you will probably want to specialize, as most professional astronomers do, in one or two lines of work. It may be photography, instrument design, star counting, classification of the kinds of stars by their colors and other information shown by their spectra, or calculation of the movement of stars which calls for knowledge in several branches of celestial mechanics. Most of the work of specialization really begins in graduate school, but you can lay a good foundation in high school and college by studying mathematics and

the use of the new computing machines which astronomers use, and by studying physics, especially the parts called optics, atomics, electricity, electronics, and mechanics. These are the tool subjects of astronomy. Most astronomers understand and use a variety of instruments. With their help, they are able to put their observations into a useful and orderly pattern.

As in nearly every branch of science, the primary requirements are a persistent curiosity and a desire to find a pattern. In this section you will be given the opportunity to make a number of observations, pursue a few projects, and build some equipment. Since much of astronomy requires darkness — the bright light of the daytime sun hides the bodies in the heavens — you will need to work on your own or in small groups. An astronomy club would be a useful organization in which you could pool your observations and equipment to move forward faster.

THE NEED TO MEASURE

The sky seems to be a great spherical bowl over our heads. For this reason astronomers make most of their measurements in angular degrees. If you draw a circle and divide it into quarters, you know that the angle at the center of each quarter is a 90° angle. The outer curve of your circle forms an arc that also has 90° for each quarter. The measurement is said to be 90 *degrees of arc.*

A whole circle, as you know from mathematics, is divided into 360 degrees. Each of these degrees is divided into 60 smaller parts, called *minutes.* And each minute is divided into 60 still smaller parts called *seconds.* It does not seem possible that a circle could be divided into so many parts — 21,600 minutes or 1,296,000 seconds. Remember, however, that the lines that make an angle start from the same center and become farther apart as they are extended outward. The distances are so vast that minutes and seconds of arc are very useful measurements in astronomy.

How big is a degree? a minute? a second? If you were to measure off one inch on the floor of a room and then view it from a height of 57.3 inches, your inch mark would cut off an angle of just 1°. Try it, using a protractor to measure the angle. The sun and moon cut off an angle of about $\frac{1}{2}$°. Hold your thumb at arm's length directly in front of you; it is about 2° wide. Hold your hand at arm's length and spread your fingers out as far as they can go; this spread, your *span,* measures about 18° to 20°. The next clear night, locate the pointers of the Big Dipper (Fig. 59); the distance between them is just over 5° and the distance between the last star in the pointer and the North Star is about 30°.

A minute of arc is only one sixtieth of a degree. This is a very small angle. Imagine a twenty-five cent piece, one inch in diameter, at a distance of 3438 (60×57.3) inches. This would be 286 feet away. Its diameter would be just one minute, *1′*, of arc. One second, *1″*, is only one sixtieth of a minute. Now your quarter would need to be 206,265 inches, or 3.25 miles, away to cover an angle of just one second. You would need a fairly good telescope to see it. Because telescopes spread out, or magnify, objects, through them astronomers are able to see details that are otherwise

all crowded together; examples would be details on Mars, or stars very close together. With photographs and measuring machines astronomers can measure shifts in the sky as small as 0.01″, or one hundredth of a second of arc.

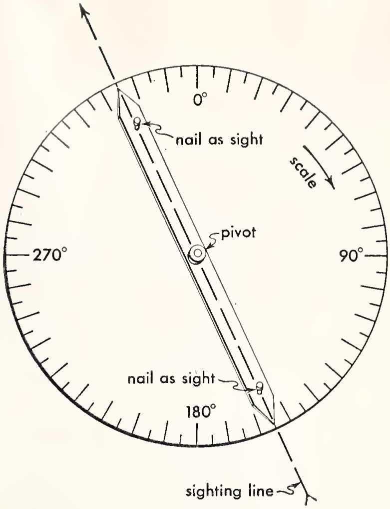
OBSERVATIONS OF THE SUN

Since it takes about a month for the moon to revolve around the earth and a year for the earth to revolve around the sun, many of your projects in astronomy take time. Let us start our observations with several long-term projects which you can start now without needing many instruments or much knowledge.

1. *The length of daylight hours*

You know that the number of hours of daylight changes between December and June. But how much? You can easily find out by making regular observations from a window that faces west and has a fairly clear view to the horizon. Once each week, as the last part of the sun disappears below the horizon, make a note of the time. If this is not practical, do the best you can; or if it is cloudy, take the next clear day. A small error in your observations will not make much difference. Keep careful records of the date and time of sunset.

Plot your observations on graph paper, using 15-minute intervals from 4 P.M. to 8 P.M. along the vertical axis and the dates along the horizontal axis. You should carry on your observations over a period of six months, using only Standard Time. Why?



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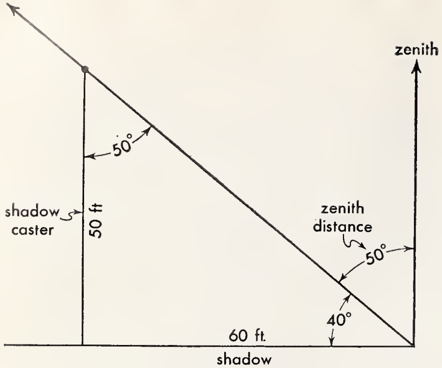
If you get up early enough, or are really ambitious, observe similarly the times of sunrise from an east window. Even a few observations — every several weeks — will permit you to derive on your own the changing length of daylight hours during the year.

2. *The direction of sunset*

Have you ever noticed that the sun sets at different points in the west between December and June? A good project is to find out how this direction varies. Incidentally, it can be combined with Project 1, if you wish.

You will need a simple device for making angular measurements. Out of a flat piece of wood and a whittled pointer, you can make a device for measuring angles as shown in Fig. 340. Using a protractor or instruments you may be able to borrow from a surveyor, civil engineer, or draftsman, you can easily mark off a degree scale. You can use stiff card-



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board, with thumb tacks instead of nails as your sighting pins.

Make your observations from a west window. Select a fixed landmark on the horizon, such as a chimney, tree trunk, fence post, or church spire. Record the number of degrees south or north of this landmark that the sun sets. Make observations at least once each week. You should plot the sunset point on graph paper, setting the degrees along the vertical axis and the weekly dates along the horizontal. The sunset point may shift by as much as 60° between December and June, so allow for this in setting up your graph.

You can also learn from your observation which point is due west from your window. It will be halfway between the extreme positions of the sun in late December and late June.

3. *Finding the sun's position at noon*

You will need a rigid vertical object sufficiently in the sunlight to cast a shadow at noon. Any object such as a flagpole or chimney will do as the shadow-caster, or *gnomon*. About once each week, record the length of the shadow when it is shortest; this will be at about 12 noon Standard Time, but not necessarily at just that moment. If you do this project on your own, a week end is a good time to make your observations. If you wish to be a little more accurate, observe at night the direction of the North Star from the shadow-caster and mark this as a line on the ground. Then at noon, record the length of the shadow at the moment it crosses this north-south line. You should record readings once a week over a six-month period.

If you know the height of the shadow-caster, you can find the angular distance of the sun at noon from right overhead (the zenith) by making a scale drawing (Fig. 341). This angular distance is known as the *zenith distance*. This angle will change by about 47° between December and June. On March 21 or September 23, when the sun is over the earth's equator, the latitude where you live is the same as the sun's zenith distance. Use a globe of the earth to check on how this occurs.

If you do not have a convenient shadow-caster near you, you can also measure the zenith distance of the sun at noon by using the instrument you used in Project 2. Suspend it from a string through a hole near the rim at 0°. Then turn the moving arm until the shadow of the top sighting pin falls on the lower one. The scale will give you the zenith distance.

4. *Making a sundial*

A sundial that tells time by the sun's shadow is based on the principle you learned in Project 3. You can

easily make a small sundial. Instructions are given in encyclopedias or in *Sundials: How to Know, Use, and Make Them* by Robert N. and Margaret L. Mayall, Branford, Boston, 1938.

5. *Investigating the sun's path*

You probably know that the earth's path around the sun is slightly oval rather than exactly circular. Can you see that one half of its path is longer than the other? You know that the sun crosses above the equator on March 21 and September 23 and is farthest south on December 22 and farthest north on June 22. These four points divide the sun's path in our sky into four equal sections.

Count the number of days on a calendar between these dates. You will be interested in the answer you get. Does the motion of the earth cause the sun to seem to move eastward more slowly during part of the year?

6. *Using a pinhole camera*

Because the sun is so bright and because sunlight has in it ultraviolet rays that would damage eyesight, we cannot observe the sun by looking directly at it. But we can view the sun by making a pinhole camera (see p. 580) and casting its image on a paper screen.

Make a "pinhole" up to ¼ inch in diameter in a piece of heavy cardboard and then fix it over a window that is otherwise covered to keep out the rest of the sunlight. Or use an old window shade instead, if you have one. Across the room, line up your paper screen with the pinhole and the sun. At 8 feet you should have an image about 1 inch across, and at 12 feet you will have an image 1½ inches across, large enough to show sunspots clearly.

Hold the screen perpendicular to the beam from the sun. Shake it gently sideways to show the solar features, which stand still as you move the paper. If you see sunspots, you can make an interesting record of how they move by making daily sketches of what you observe.

If you would like to try to make a permanent record of your observations, you may be able to photograph them by making a pinhole in the cover of a long tube and placing a piece of photographic paper inside the other cover. You will need to devise a means of lining the tube up with the sun so that the image will fall on the photographic paper and not on the sides of the tube. Uncovering the pinhole for a few seconds would act as a shutter (see p. 580).

7. *Observing the sun by telescope*

Before you begin, a word of WARNING: NEVER LOOK AT THE SUN THROUGH BINOCULARS OR A TELESCOPE. You can damage your eyesight.

By mounting binoculars, or a telescope, on a stand and pointing it directly at the sun, you can focus the sun's image on a sheet of paper. This image will be larger and sharper than the one you could obtain in Project 6. With binoculars you can obtain an image about 6 inches across on a screen 10 feet away. By careful adjustment of the focus, you can see considerable detail in sunspots — if there are any big enough to show on the screen.

OBSERVATIONS OF THE MOON

The position of the moon continually moves eastward around the sky, returning to the same point once every month. During this time one full cycle of moon phases takes place. These changes offer opportunities for several kinds of observations.

8. *The moon's phases*

A good time to start observations is at the next full moon. Sketch as carefully as you can the shape of the moon, and if you have the use of a telescope, sketch in also the features you see on the surface. At least once each week — several times will be better — make similar observations of the waning moon, the new moon, the waxing moon, until full moon again occurs. Make sketches for each phase of the moon and determine the angular distance from the sun. Notice that often you can see the moon during the daytime — when the sun is up.

How does the appearance of the moon change as its angular distance from the sun increases and decreases? At what phases does the moon appear to be east of the sun? West of the sun? Does the appearance of the surface features of the moon change?

9. *The length of the lunar month*

Over several months determine as carefully as you can the time of the full moon. Newspapers give the times, but you should also check these times with direct observation. When you start your observations, sketch the moon and near it the bright stars you see.

How long does it take for the moon to get around the sky and back to the same group of stars? This interval will be about two days less than the time between the full moons. Why? How is the changing interval related to the eastward changing position of the sun in the sky? Which of the intervals is the "month" most near our calendar month in length? How many full moons occur in a calendar year?

10. *Distance to the moon*

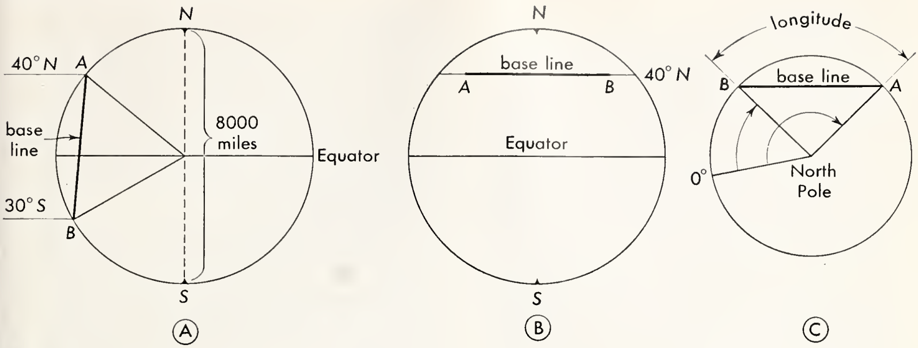
One of the tools of the astronomer is mathematics. This project gives you an opportunity to try some fairly simple problems.

The earth is about 8,000 miles in diameter. If we could look at the moon from both the North Pole and the South Pole at the same time, we would notice a shift in the moon's position by about 4 times its diameter. You will recall (p. 626) that the diameter of the moon as we see it is about $\frac{1}{2}°$; hence the angular shift would be four times that or about 2°. Your baseline would be the earth's diameter of 8,000 miles.

At the beginning of this section we said that one inch at a distance of 57.3 inches cuts off an angle of 1°. Or, two inches at that distance would cut off 2°. For an object to cut off an angle of 2° its distance must be about 30 times its actual diameter. Therefore we conclude that the moon's distance is about 30 times the earth's diameter, or 30 times 8,000 miles, which is 240,000 miles.

Perhaps you noticed that no matter how large the object is, or how far away it is, as long as it has an angular

Baseline of B as seen from the top



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diameter of 1°, its distance would be 57.3 times its actual size. In mathematics this ratio of sides in a triangle is known as the "tangent of the angle," and for 1° it is 1/57.3 or 0.0175.

We cannot make simultaneous observations from the two poles, but we can from two points far apart on a north-south line or an east-west line. If you and a friend in Argentina or Chile were to observe the moon at the same moment, the moon's position would be shifted by about one degree against the stars. You could measure this shift if each of you made a careful plot of the moon's position and then exchanged the plots.

How to find the distance between you needs a bit of explaining. As in Fig. 342A, draw a circle having a diameter of 8 inches to represent the 8,000-mile diameter of the earth. With a protractor mark your latitude north of the equator and the latitude of the observer south of the equator. Connect the two points with a straight line and measure its length. Then, with this as your baseline, with the angle about 1°, measured from the plottings of the moon's position, and with a table of tangents, you can easily get the distance of the moon.

If your observer is directly west of you, as in Fig. 342B, mark off the latitude on your 8-inch circle and connect the two points. Now imagine you slice off the section above *AB*, cutting along the line of latitude 40° N. You would have a smaller circle as in Fig. 342C; its diameter is the farthest you could be apart at that latitude. Now select any point on the circle and mark it as 0° longitude. Then in a clockwise direction mark off the two longitudes (we assume they will be both west of Greenwich). Connect the two points on the circle and measure the distance (1 inch = 1,000 miles) and get the number of miles. Given this figure as your baseline, the angular measurement of shift noted from the two positions, and a table of tangents, you can calculate the moon's distance.

Astronomers use many modifications of this technique to measure the distance of stars and earth satellites. Of course, the farther away an object is, the smaller the angle will be. Do you see why astronomers have to work with minutes, seconds, and even hundredths of seconds in measuring the distant stars?

Try these:

1. The base line between two observers is 4,000 miles. If the moon is 230,000 miles away, what is the tangent of the angle of shift? If you have a table of tangents, what is the angle?

2. Two observers 500 miles apart observe an earth satellite at the same time. The angle of shift is found to be 8°. How far away is the satellite?

3. Two observers of a satellite find the angle of shift to be 12° and the height of the satellite is known to be 600 miles. How far apart are the observers?

4. A satellite is traveling in an oval orbit. At its closest point to the earth it is 300 miles away; at its farthest point, it is 600 miles away. At which point will the angle of shift be greatest? Can you show how the angle of shift measured from a number of points on the earth's surface can be used to plot the orbit of an earth satellite?

11. *Fixing the moon's position*

As the moon moves across the sky, changing its position about 13° per day, it frequently passes in front of stars. Such an event is called an *occultation*. Watch the moon until you notice a star slightly east of it. Continue to watch as the moon moves nearer. Abruptly the star will disappear. Record the time to the nearest second. Of course, write down the date, too. This is the kind of information from which astronomers, knowing your exact location, can determine accurately the position of the moon in the sky at that moment.

How soon will the star reappear? Keep watching at intervals of five or ten minutes. The star will reappear suddenly on the other side of the moon, but it may be an hour or more before this happens. Record this time, too, to the nearest second. Since the star disappeared and reappeared suddenly, what can you conclude about the moon's having much of an atmosphere?

Although not essential, binoculars or a small telescope are useful for occultation observations. They allow you to see fainter stars near the bright image of the moon and also magnify the field so that you can more readily watch the approach of the moon to the stars in its path.

12. *Predicting tides*

The moon, as you know, exerts a pull on the earth's waters, resulting in tides. How is it possible to set up accurate tide tables in the newspapers or on tide calendars for a year in advance? If you live near the seashore, you can learn how to predict tides with reasonable accuracy — at least over a short period.

The high tides follow by some interval the instant the moon crosses your local north-south line. To establish a north-south line, observe a point on the horizon directly below the Pole Star. Then locate a point on the horizon directly opposite. You can find this point by using the instrument suggested in Project 2. If convenient, stretch a wire overhead along this north-south line, making your observations from directly below the wire. You will soon be able to determine within a few minutes the time the moon crosses this line overhead.

Your problem is to establish a record of the interval between this time and the next high tide. To do this,

record the exact time the moon passes the north-south line and record the time of the next high tide, using a tide table or your own observations at the seashore. Take the difference between the times. This interval is known as the *establishment of the port*. Records over several weeks or months will be useful to show small periodic variations in the predictions. After a few weeks, you should be able to predict the time of high tide fairly accurately for several days following a single observation.

You may also wish to record the height of the tide every day for a month. You will find variations as explained on p. 169. Keep a record of your observations and compare your high and low tides with those recorded for other parts of the world.

TELESCOPES AND CAMERAS

Up to now, any of the projects in this section can be done without the use of a telescope. While some of the later projects can also be done with the unaided eye, a telescope will be helpful. It will also make an entirely new set of observations possible to you.

If you do not have a telescope, perhaps you can borrow one until you decide how interested you are in astronomy and how much you can afford to spend. If you have an astronomy club, perhaps it can finance the purchase of a telescope for the use of the members. Used telescopes — they do not wear out with use — may be available. Or you may wish to buy the parts and assemble your own instrument. Consult advertisements in various popular journals of astronomy, or try to talk with a nearby amateur telescope maker, or write to a nearby planetarium, college, or observatory for advice.

All over the country there are amateur telescope makers who have already made excellent instruments. Usually they are pleased to have someone interested in using their telescopes. They may even be willing to come to talk with a school group once or twice. A nearby museum or the science writer of your local newspaper can put you in touch with someone. Or you can write to Mrs. Wilma Cherup, 4 Klopfer St., Millvale, Pittsburgh 9, Pa., who is secretary of the Astronomical League. Consult, too, the magazine *Sky and Telescope* for notices of meetings of amateurs and addresses of local officers.

13. *Making your own telescope*

If you wish to make your own telescope from the very beginning, as many people have, you are in for considerable work and a great deal of fun. You can find full instructions in these publications:

Making Your Own Telescope by Allyn J. Thompson, Sky Publishing Corp., Cambridge, Mass.

Amateur Telescope Making, Albert G. Ingalls, Scientific American Publishing Co., New York, 1957.

For further reading, see also the "Amateur Astronomer" page, which ran for many years in the *Scientific American*, and "Gleanings for ATM's" in *Sky and Telescope*.

Should you wish to silver a mirror

of a telescope or any other piece of glass, you will find instructions in the physics and chemistry handbook which you may borrow from one of your teachers, or a local library.

14. *Taking pictures through a telescope*

Once you have a telescope, one you have made or purchased, you will need a firm mounting so that you can set the instrument and have your hands free for sketching and taking notes — or so that your friends can look, after you have adjusted the instrument. With a fixed mounting, you can also take snapshots of bright objects by holding the lens of a camera at the eyepiece.

To take longer exposure photographs, you must mount the telescope with a polar axis and provide a clock drive to move it at the rate the stars move westward. The procedure is more complicated than we can discuss here.

1. Let us say you want to photograph the moon. First focus the telescope for a sharp image; then hold your camera to the eyepiece and make a short exposure, say $\frac{1}{30}$ of a second. In this way you could make a series of enlarged pictures of the moon's phases, or of the progress of an eclipse of the moon. At the totality of eclipse a considerably longer exposure would be needed to show the faint moon, which does not entirely disappear.

2. If an eclipse of the sun occurs, you can make an interesting photographic record even if the eclipse is only partial. Do not try to photograph the sun directly; instead use a pinhole and a screen as described in Project 6. Then photograph the image on the screen. You will get pictures of the moon covering part of the sun.

CONSTELLATIONS AND PLANETS

As you have observed, the moon makes a complete circle around the earth. And the planets move around the sun. The constellations swing each day across the sky, but their location remains relatively fixed in the heavens. Hence, to observe the motions of the planets and the moon and to record their positions, you must be familiar with the constellations.

All the sky is divided among 88 constellations. Some are large and some are small. Some include many bright stars and some include none that are conspicuous. By international agreement, the official boundaries of all these constellations now run along north-south and east-west lines. Surely you will wish to become acquainted with the thirty or forty conspicuous constellations that can be seen from your position. Like the old observers, you will find the twelve zodiacal constellations of most importance, because they occur along the band within which the sun, moon, and planets move.

The names of the twelve zodiacal constellations are:

Aries, the Ram ♈
Taurus, the Bull ♉
Gemini, the Twins ♊
Cancer, the Crab ♋
Leo, the Lion ♌
Virgo, the Virgin ♍
Libra, the Balance ♎
Scorpio, the Scorpion ♏

Sagittarius, the Archer ♐
Capricornus, the Goat ♑
Aquarius, the Water Carrier ♒
Pisces, the Fishes ♓

Other constellations you will wish to recognize are: Andromeda, Auriga, Boötes, Canis Major, Cassiopeia, Cepheus, Cygnus, Hercules, Lyra, Orion, Pegasus, Perseus, and Ursa Major and Ursa Minor, which include the Big and Little Dippers. These can all be seen from the Northern Hemisphere.

Within the constellations are thousands — even millions — of stars.

The names or designations of stars may seem confusing. Some go by three or more different labels. Long ago the brightest stars were given names. Some of these were changed by the Arabs during the Middle Ages, like Algol (AL-gol) — which means the *Ghoul* or *Demon*. Later, when more careful star maps were made, the stars in each constellation were assigned Greek letters, *Alpha* (α), *Beta* (β), *Gamma* (γ), *Delta* (δ), etc. Most of the brighter stars we can see easily are known by these Greek letters. Then later the fainter stars were identified in each constellation by their number in someone's catalogue. So we have Polaris as also Alpha Ursa Minoris, and Algol as Beta Persei (meaning *Beta "of Perseus"*).

15. *Locating stars and constellations*

You cannot make further progress until you learn how to locate the constellations and some of the brighter stars. For your first observations, the star maps in an encyclopedia will be useful. More detailed and useful star maps are to be found in *Norton's Star Atlas and Telescopic Handbook* by Arthur P. Norton and J. G. Inglis, 1950. It was published in England but it is available through various planetariums and from the Sky Publishing Corp., Harvard Observatory, Cambridge 38, Mass. The price will be about $5.00.

An even more extensive star map used often by professional astronomers is the *Atlas of the Heavens, Atlas Coeli*, 1950, prepared by A. Becvar and others, in Czechoslovakia. It is available from the Sky Publishing Corp.; the accompanying *Atlas Coeli Catalogue* (about $5.00) lists the positions of hundreds of stars, star clusters, planetary and diffuse nebulae, and galaxies.

1. You may start observing constellations by using a star map and trying to find the position of the constellations in the sky. You should learn how to locate at least a dozen of the constellations listed in the catalogue mentioned above. Make sketches of what you observe. Since the positions of the constellations in the sky change with the seasons, you will find it interesting to make observations at monthly intervals and compare your sketches.

2. You may photograph the constellations with a camera at monthly intervals and compare your films to note the changing positions of the constellations. Here are some of the photographs you could take.

a. If you set your camera securely in a dark place, aim it toward the Pole Star, and make a time exposure for several hours, you will get an interesting pattern of circular star trails. Notice that the bright Pole Star makes a little circle; this means that it is not exactly over the earth's

north pole but only approximately right above it.

b. If you set your camera securely and aim it at a constellation, time exposures of 30 seconds or a minute will give you pictures of the star patterns. You might take the same photograph with two types of film and see the difference in the brightness of the stars when photographed in blue and in panchromatic light. Use a plain film — not dyed — for the blue picture and an ortho- or panchromatic film for the way your eye sees the sky. If you add a yellow filter when you use a panchromatic film, you will increase the difference. From the two pictures you could pick out the stars that are bright on the red film, but faint on the blue. These would be the numerous yellow or red stars, like Betelgeuse in Orion. Astronomers use this method to determine the colors of faint stars.

If you were observing variable stars (stars that change in brightness) and found one, like Algol, near its minimum, you might photograph it for comparison with another picture when it was normal. Similar pictures without a telescope could be made of Delta Cephei and of Beta Lyrae.

16. *Observing the visible planets*

Among the most puzzling of astronomical observations have been those of the motions of the planets. You can observe five bright planets without a telescope. Two, Mercury and Venus, are always in the part of the sky near the sun, sometimes east of it and visible in the evening, and sometimes west of it and visible in early morning.

More confusing are the motions of the three other planets, Mars, Jupiter, and Saturn. These appear to move eastward completely around the sky. About the time they are opposite the sun, they cease their eastward motion, come to a standstill, and then move westward for some months only to stop and again move eastward. The westward motion is called *retrograde.*

On a simple star map, or by means of photographs, make weekly observations and careful records. You will be able to plot the strange motion of these planets and also notice that they are brightest when opposite the sun. Notice where the planets are in relation to the constellations.

If you make careful observations of Mars over a long period, you will discover it to be opposite the sun at intervals of about 2 years and 50 days. For example, on the following dates, Mars is opposite the sun and in these constellations of the zodiac:

1960 December 30 — Gemini
1963 February 4 — Cancer
1965 March 9 — Leo

17. *Observing the invisible planets*

To observe Neptune and Uranus, and the satellites of Jupiter and the rings of Saturn, you need the help of binoculars or a small telescope.

First, you can observe Uranus, one of the very few greenish objects in the sky. And you can observe Neptune. But to find where they are you will need a predicted position, called an *ephemeris.* Such timetables for many celestial bodies are published by the government annually and well in advance as the *Astronomical Ephemeris and U.S. Nautical Almanac.* It is available from the U.S. Govern-

ment Printing Office, Washington 25, D.C., and also from many bookstores and stores that carry marine supplies. To use the tabulated positions, some form of star map is also essential. Each year a sky map showing the positions of Uranus and Neptune among the stars is published in the January issue of *Sky and Telescope*, a popular astronomical monthly publication. Uranus has recently moved into Cancer, and Neptune into Virgo.

With a little optical help you can also observe the four satellites of Jupiter, discovered in 1610 by Galileo. You should make frequent observations of their positions and record them in sketches. From them you may be able to determine the periods of motion of these satellites around Jupiter. You will also be able to observe the beautiful rings of Saturn and notice their slowly changing appearance as Saturn moves around the sun. You should make sketches of these, too.

18. *Model of the earth in space*

Now that you have learned something about the heavens and the location of planets and constellations, you may wish to try to make a model, using a round-bottom flask, which your science teacher can obtain for you. You can easily make a model of the earth in space. From it you can see how the appearance of the sky changes if you go northward or southward and how the stars appear to rise and set.

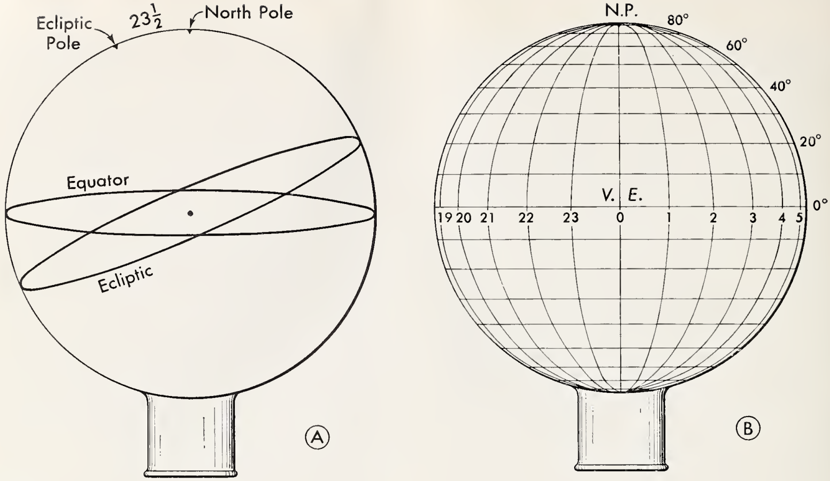
To make this model all you will need in addition to the round-bottom flask is a one-hole rubber stopper to fit its neck, a piece of glass tubing, paint, a fine brush, a table of star positions, and considerable patience.

On the bottom of the flask locate the point opposite the center of the neck. Mark this point "North Pole." With a string or tape, determine the circumference of the flask — the greatest distance around it. This will be 360° in your model. Then, starting at the North Pole, measure off frequent points that are $\frac{1}{4}$ of the circumference, or 90°, from the North Pole point. Mark each point. These points should lie in a line around the flask, which will be the equator. You can mark in the equator with a grease pencil (china-marking pencil), with paint, or India ink.

To locate the stars accurately on your "globe of the sky," you will need a coordinate system. If you do not wish to have the coordinate system marked permanently on your model, put on the lines with a grease pencil. To set up the coordinates, from the North Pole mark a point $23\frac{1}{2}°$ (about $\frac{1}{4}$ of 90°) away. This will be the *pole of the ecliptic* (Fig. 343A). Draw a line through the North Pole and the ecliptic pole down to the equator; this point on the equator is the *vernal equinox* (Fig. 343B), where the sun is located on March 21. All positions in the sky are located eastward from this point, and north or south from the equator.

To set up the north-south scale, which is like latitude on the earth but called *declination* in the sky, measure off points $\frac{1}{9}$ of the way from the North Pole to the equator and draw through these points little circles that run east and west. These lines will be 10° apart, which is close enough for spotting in your stars.

To set up the east-west scale, mark from the vernal equinox intervals of $\frac{1}{24}$ of the total circumference. These marks will be 15° apart. We use this



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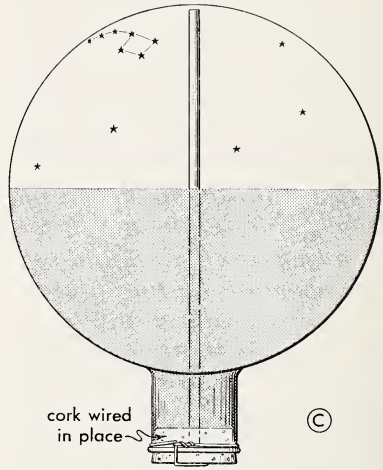


interval rather than 10° marks because the sky turns through 15° each hour and star positions are recorded in "hours eastward from the vernal equinox," called their "*right ascension.*"

Now your globe looks like a big piece of curved graph paper. From a table of star positions you can spot in a star's position north or south of the equator. All east-west positions are expressed eastward from the vernal equinox — on your globe these will be to the *right* of that point.

If you wish, you can mark off and draw in the great circle of the ecliptic, which will be 90° from the pole of the ecliptic (Fig. 343A).

To finish the model, put the glass rod into the stopper so that it almost reaches across the flask and points to your North Pole point. Then put in the flask enough inky water so that, when you hold the neck straight down, the water just comes up to the line of the equator. For safety, wrap wire around the neck of the flask and over the stopper so it will not fall out.

Now, no matter how you tip the flask, you have a picture of the sky as you would see it. If the North Pole is straight up, you are at the North Pole of the earth and you see stars in only the northern half of the sky. As you rotate the globe from right to left, the stars will move as you would see them from the earth. If you tip the pole down halfway, you are at latitude 45° N. As you turn the globe, stars will rise above the

Annual Meteor Showers

Name	Date of Maximum	Radiant R.A.	Radiant Dec.	Radiant Vel.	Best Observing Time
Quadrantid	January 3	231°	51°	41 km./sec.	A.M.
Lyrid	April 21	280°	37°	49 km./sec.	A.M.
Delta Aquarid	July 29	340°	−17°	40 km./sec.	All night
Perseid	August 12	45°	57°	60 km./sec.	A.M.
Orionid	October 22	96°	15°	66 km./sec.	A.M.
Leonid	November 17	152°	22°	72 km./sec.	A.M.
Geminid	December 12	113°	32°	35 km./sec.	All night

"sea" in the east and set in the west. If you hold the globe with the earth's axis horizontal, you are at the equator. Then all the stars can be seen as they rise and set.

METEORS AND COMETS

Meteors, commonly called *shooting stars*, appear when small bits of matter dash into our atmosphere at many miles a second and are turned into hot gas. This is what happens also when an earth satellite loses altitude and enters the earth's atmosphere.

On the average, you may see about ten meteors per hour if you have a very dark sky with no moon and free of the glare from street lights. At some times of the year, there are meteor showers when large numbers may be seen in a short time. The strongest of the annual meteor showers are shown in the table on this page.

Other strong meteor showers occur at longer intervals. At present the strongest of these is the Draconid shower, which occurs every 13 years on October 9, the most recent being in 1959. The shower was very strong in 1933 and in 1946. Its next appearance presumably will be 1972. This swarm of particles is associated with the short-period comet, Giacobini-Zinner, which passes near the earth at intervals of 6.5 years. The meteor swarm appears to be close to the parent comet and has not been detected in those years when we pass the comet's orbit half a year ahead or behind the comet. This shower, like some others, is intense for only a few hours. Some showers are more diffuse and last for several days.

19. *Plotting meteor trails*

Meteors may be members of a shower or be sporadic (non-shower). If you wish to observe meteors and plot their trails, select a dark night and an observing place that is comfortable and away from the glare of street lights. Take with you star maps on which the straight lines are great circles and a red-covered flashlight that will not cast a glare and yet permit you to plot your observations. You may be able to obtain the maps you need, perhaps at small cost, from

the American Meteor Society, c/o Dr. C. P. Olivier, 521 N. Wynnewood Ave., Narberth, Pa.

For each meteor you see, plot its trail on your map. Extend the trail backwards. After you have plotted ten or more meteors, you may be able to decide whether you have seen a meteor shower, sporadic meteors, or both. (*Hint:* If the trails of many extend backwards to a point, these meteors are members of a shower.)

20. *Photographing meteors*

If you have much patience and a really dark sky, you can try photographing meteors. Load your camera with the fastest film and open the iris wide. If your sky is really dark, you can make exposures of an hour or more without the film becoming much fogged. On the average you may expect to record one meteor trail in each hundred hours of exposure. But when a strong meteor shower comes, as in August when the Perseid meteors appear, you may be able to get a trail recorded in ten hours. The best direction in which to point your camera is about 30° to 40° above the horizon. Of course, your camera must be firmly fixed in a rigid support.

21. *Discovering comets*

At the present time almost half of all comet discoveries are made by amateurs. While the professional astronomer is more likely to find faint comets showing on his photographs of the sky, bright comets are "open season" for anyone — and there are more amateurs than professionals. One amateur astronomer and observer of variable stars has twelve comet discoveries to his credit! Also, several recent bright comets have been first seen by school children.

The best place to search for new comets is the region above the sun at sunset and sunrise. A fair fraction of the brighter comets, which come in close to the sun, move toward the sun on the side opposite to where the earth is. We cannot see them because of the sun's brightness. But when they pass close to the sun and change direction, they suddenly pop out in the twilight sky.

With binoculars you may sweep the sky looking for faint fuzzy objects. There are many in the sky — which are *not* comets. These are the star clusters, galaxies, and great clouds of gas called nebulae. To make sure that you do not issue a false alarm, you will need to check any suspected object against a good star map that shows the known objects. Also, sketch its position and watch closely for a bit of motion. If it is fuzzy *and* moves among the stars, it is probably a comet. Then, notify the nearest large observatory at once. Astronomers want to know as soon as possible when something new has been found. Also, comets are named for those who first observe and report them.

BRIGHTNESS OF STARS

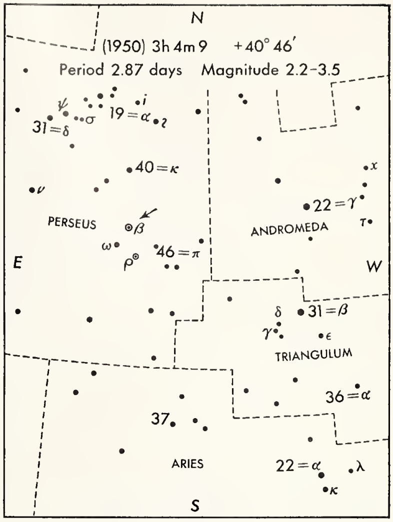
Several of the brighter stars you can see vary in brightness by enough to permit interesting observations. Some suggestions on how to estimate a star's brightness are necessary. Algol, the *Demon* star, also known as Beta (β) Persei, is a double star with one bright star and one faint star. Let us assume that you are observing Algol. Figure 344, reproduced by

permission of the American Association of Variable Star Observers (A.A.V.S.O.), shows the area around Algol with the brightness magnitudes of comparison stars indicated. For convenience the decimal points are omitted; thus the magnitude of Alpha (α) Persei is given as 19 when it is actually 1.9. The star near Algol would seem to be ideal for comparison, but it is itself a red variable star that changes in magnitude from 3.4 to 4.2. The minima of Algol, as well as planet positions, are given in *The Monthly Evening Sky Map* (now a quarterly), 69 Beckwith Place, Rutherford, N.J.

It is necessary, for comparison, to select one star that is brighter than Algol, the one you are observing, and another that is fainter. Gamma (γ) Andromeda (22), and Beta Triangulum (31) answer the purpose. You estimate that Algol has a brightness halfway between these stars you have selected — a difference of 9. You would write in your record: "γ And. ½ β Tri." with the date and time of your observation to the nearest few minutes. Later you can derive the magnitude; thus, inserting decimals in the magnitude values:

$$2.2 + \tfrac{1}{2} \times 0.9 = 2.65 \text{ (magnitude of Algol)}$$

Algol (Beta Persei)



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22. *Observations of Algol*

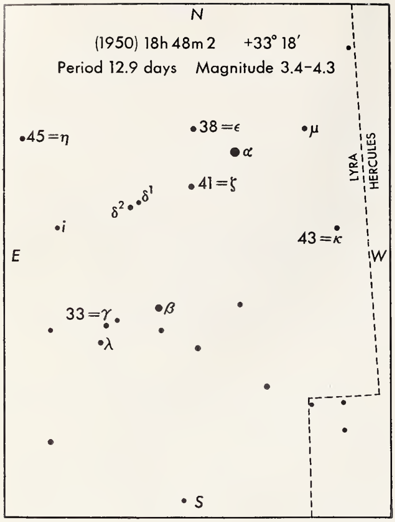
The brightness of Algol varies with a definite period of 2 days, 21 hours — or 69 hours. The times of maximum and minimum brightness can be predicted and are published in the magazine *Sky and Telescope*. But you can make a search for the minimum brightness yourself.

Each three days the eclipse of the bright star by the faint star will come three hours earlier. In eight cycles or 23 days it will have moved around the clock and reoccur at about the same hour. Since you can easily notice the change in brightness for at least three hours, a regular watch at the same hour each night — weather permitting — should allow you to detect an eclipse within 23 days. When you observe an eclipse, make observations every 15 minutes. A plot of these observations will indicate the time of minimum from which you can accurately predict the next eclipse. From a long series of observations you can determine your own value for the period.

23. *Observing other variable stars*

Three other variables are easily observed, but they have quite different characteristics.

1. Beta Lyrae is near the bright star Vega (Alpha Lyrae) which



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passes overhead in the evening during the summer months. Its period is 12.9 days and its brightness varies in magnitude from 3.4 to 4.3. You will observe a minimum every 6.45 days.

2. Delta (δ) Cephei is west of Cassiopeia and can be observed most easily in the evenings of the autumn. Its period is 5.366 days; it is not an eclipsing star like Algol or Beta Lyrae, but one which seems to swell up and shrink rhythmically. There are a large number of similar variables, known as the Cepheid variables. You can locate Delta Cephei from Fig. 346 and estimate its brightness by comparing it to the stars of known brightness indicated in the figure.

If you observe this star, you may wish to make several observations a few hours apart each night because its brightness rises rapidly from a minimum of 4.5 to a maximum of 3.2 in about 36 hours.

3. Omicron Ceti, also called Mira, is reported to have been the first star recognized as a variable one; this was in 1596. It has a period of 332 days and varies through a great range from about magnitude 2 to 4 at maximum to about 9.5 at minimum. It is located in a field of fairly faint stars about 6° southeast from Alpha Ceti and about halfway between the two stars Delta and Zeta (ζ) Ceti. Mira is just south of the equator and about 3 hours west of Orion, so it is best seen in the evenings during the autumn and winter months. At maximum brightness it can be seen without binoculars, if the sky is clear and dark. Most observations of it will, however, probably require binoculars. It can be located with the aid of a general star map and Fig. 347.

If you have a small telescope and wish to observe Mira at or near minimum brightness, you will need to use Fig. 347B). As most telescopes invert the field of view, putting north at the bottom and east on the right, this

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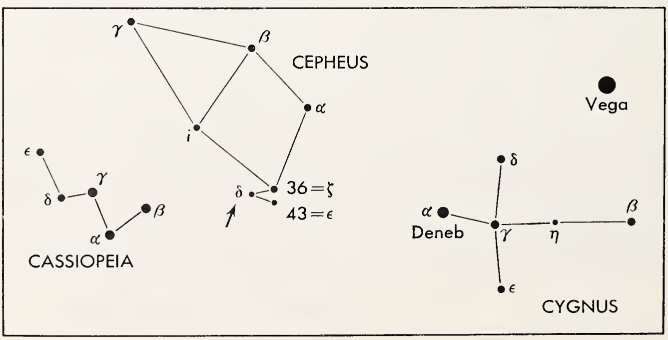


figure is reversed from Fig. 347A. Notice that a star of magnitude 9.2, about the minimum brightness of Mira, is just to the east of the variable.

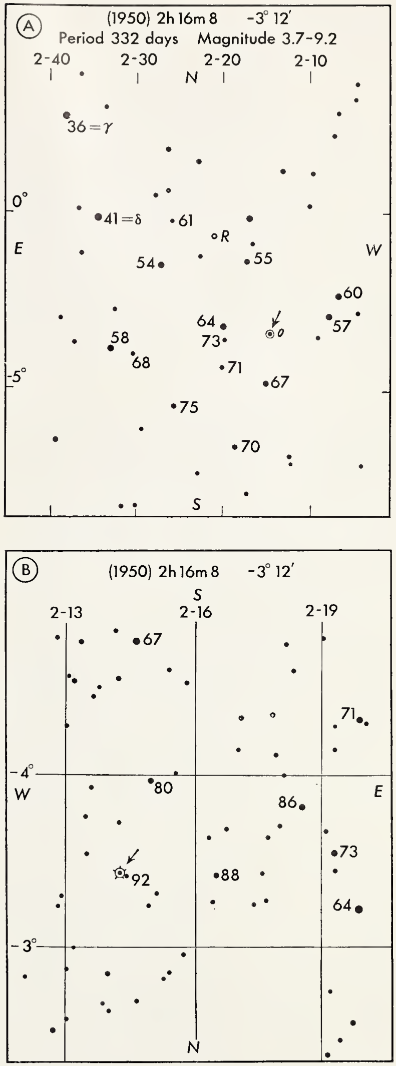
4. If you are interested in observing other variable stars and contributing to the useful reports made by amateur astronomers, you could contact the American Association of Variable Star Observers, 4 Brattle St., Cambridge 38, Mass., for more information. This group has many hundreds of members throughout the world and helps keep watch on hundreds of variable stars. A *Manual for Observing Variable Stars* by the Curator, Margaret L. Mayall, sells for $1.00.

24. *Locating novae*

For reasons astronomers do not yet understand well, some stars abruptly flare up to a million times their original brightness. Such a star is a nova, or "new star." Since no one can tell when or in what part of the sky a nova will appear, observers who are familiar with star patterns keep a sharp watch to note any sudden change in brightness which may indicate a new star.

You may be the first to notice a nova, but you need to be familiar with star patterns, and of course you must check any suspected object to make certain that it is not a long-known star, a bright planet, or some other familiar object. Should you be fortunate enough to find a nova, you should follow this procedure: Note the position of the object carefully, sketching it in relation to known stars; set down the exact time of your observation; estimate its brightness as directed in Project 23, noting any rapid changes in brightness; and then

Mira (Omicron Ceti)



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report your discovery *at once* to a large observatory near you. Of course, such a discovery would be exciting and you would wish to watch the behavior of the nova over as long a period as possible. You may

even be able to get a series of interesting photographs.

25. *Observing clusters of stars*

There are several kinds of star groups, ranging from double stars to great clusters and galaxies. With a telescope you can observe variable stars that are fainter than those you could view with binoculars. Literally hundreds of such stars are known and more information about them is wanted.

One double star that is easy to observe is Beta Cygni, which consists of a yellow star (magnitude 3.0) and a blue star (magnitude 5.3) separated by only 35 seconds of arc. There are hundreds of similar interesting double stars.

The Pleiades seem to have only a small number of stars, but when seen through a telescope, this star group is seen to have more than a hundred stars moving together through space. It is one of the great star clusters. In the constellation of Hercules there is a rich globular star cluster. It is about 13,000 light-years away and contains several hundred thousand — perhaps more than a million — stars.

Some of the great galaxies, like that in Andromeda, can be seen clearly through a telescope. The light from even the nearest galaxy takes over a million years to reach us. The surface of these galaxies is luminous; hence to show best, they should be observed with low magnifying power. However, no observation by eye can see the extent of a galaxy or the detail that long-exposure photographs can record for close study.

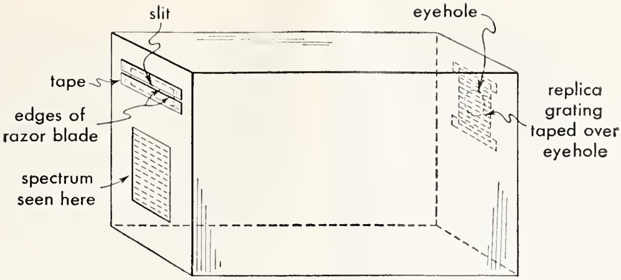
Let us assume you are interested in studying double stars, star clusters, or entire galaxies. You will need a good star map like Norton's (see Project 15), which contains all the information you need. Again you will follow the technique of recording, as we have suggested in earlier projects.

26. *Examining the light of stars*

Earlier projects have suggested that stars differ in color — red stars, yellow stars, and blue stars have been mentioned. Perhaps you know that elements, when they are hot, give off different colors of light. The temperature at the surface of most stars is high enough for all the known elements to shine and give off light.

You have read (p. 303) that at their centers the sun and stars are constantly turning hydrogen into helium, but astronomers have discovered that stars have other elements in them such as iron, calcium, and magnesium. You may have read that the atmospheres around Jupiter, Saturn, and Uranus contain a great amount of ammonia and methane gas. How did astronomers find these chemical elements in such distant objects? Every glowing object gives off light. If this light is passed through a prism, the light spreads into a band of colors (p. 552) called the spectrum. Each element shows certain characteristic bands of color when the light is viewed through a spectroscope. Astronomers learn much about stars with such a device or by photographing a star's spectrum with a spectrograph.

While you probably cannot analyze the light of distant stars and planets, you can easily detect several chemical elements in the sun by using a shoe box spectroscope which you can easily build.



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You will need these materials: one shoe box or any other long narrow box with a top, a double-edged razor blade broken in two, masking tape, and a square inch of replica grating. This grating has about 14,000 lines to the inch, and is available in an 8 × 11 inch sheet from Edmund Scientific Company, 101 E. Gloucester Road, Barrington, N.J. The item number is #40,267 and costs about $1.50.

Figure 348 shows how these materials are arranged. At one end of the box, near a corner, cut a narrow slot not quite as long as the razor blade. With masking tape, attach on the inside of the box your two halves of the razor blade so that the blade edges are about ½ millimeter apart, forming a narrow slit over the slot you cut in the box. Opposite the slit, at the other end of the box, cut an eyehole about one inch in diameter. Over this, but inside the box, attach a piece of replica grating with tape. The lines of the grating should be parallel to the slit. With thumb pressure adjust the width of the slit until a dark line appears down its middle. If this does not let in enough light, the slit may be opened slightly. Put the top on the box and aim the slit at the sky near the sun.

As you look through the eyehole, you will see bright bands of color on either side of the slit. These bands are the sun's spectrum. Vertically across this spectrum you will see faint dark lines, probably like those in Fig. 349. How do we know which chemical elements caused these lines?

You can find out quite easily. Look through your spectroscope at various bright gases such as neon and argon in neon and argon lamps. Or wrap a salt (sodium chloride) wick around a Bunsen burner and sight on the burner to see a sodium flame. You will discover that each element has its own pattern of bright lines. A bright ordinary lamp bulb, which has a hot solid wire as its filament, shows a continuous spectrum, one without lines. If you place such a bulb behind the hot gas you are examining, the bright lines will now show as dark lines in exactly the same place. By testing a known element in a laboratory, one can find its

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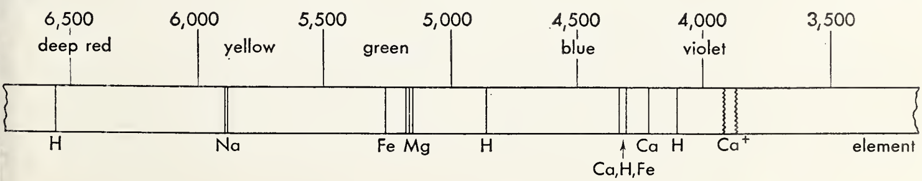

pattern of bright lines. Then if an unknown substance in a light source or a distant star contains the same lines, we know that the substance or star contains that element.

27. *Photographing star spectra*

Set up your telescope away from any source of glare on a dark night and then place a sheeting of your replica grating over the lens. Through the eyepiece you will see colored streaks of light, which are the spectra of the object your telescope is pointed at. You may have to make several trials, for only the brightest stars will give enough light to reveal their spectra.

Probably you will not be able to see the faint dark lines. But you may be able to photograph them if you can mount a camera securely over the eyepiece. Turn the grating so that the lines run horizontally; the spectra will then appear above and below the central image. Possibly you may have to offset your telescope so that the spectrum you want shows in the eyepiece. Then clamp on your camera, open the shutter for a time exposure of a minute or two. The westward motion of the star will spread its spectrum sideways on your film so that the individual spectral lines may show.

Start with a bright star such as Sirius or Vega — both of which show strong lines characteristic of hydrogen. You may also be able to photograph interesting spectra of Mars, Jupiter, and Saturn. Mars will look like reflected sunlight, but Jupiter and Saturn will show large absorption bands due to the molecules in their atmosphere.

DEMONSTRATING MOTION OF PLANETS

Two demonstrations you may be interested in doing will show you the motion of planets and satellites as they revolve about their orbits and the rotary motion of the earth.

28. *A model of planet or satellite motion*

If you have or can get the use of a lathe, you can with a bit of skill make a wooden or metal model to show how a planet or comet moves around the sun or a satellite moves around the earth. You need to shape a surface that slopes down toward a central point so that a marble or a ball bearing rolling on the surface experiences the same type of pull that a planet or a satellite receives from the body around which it revolves.

The curving surface you would construct with the lathe would look like the graph in Fig. 350. That is, as

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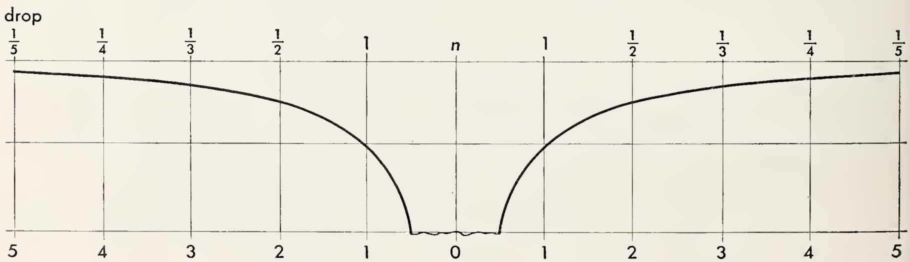
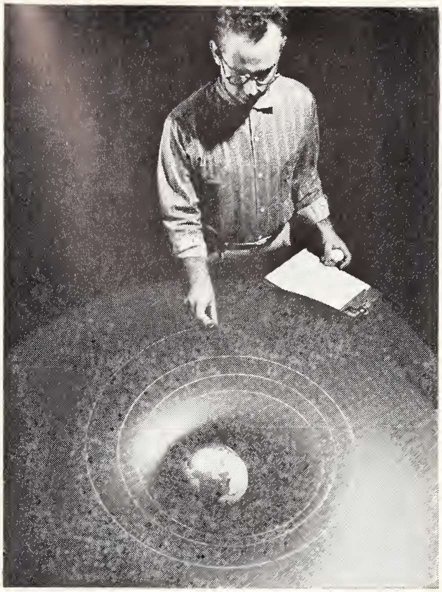


the curve nears the center, the surface drops by an amount inversely proportional to the distance from the center, which will be the deepest point. Or, in other words, the drop varies as $1/d$ where d is the distance from the center. Such a surface has the shape shown in Fig. 351.

After you have made your model, you can demonstrate planet or satellite motion. Set a smooth marble or ball bearing on the surface; it will roll into the center. If, however, you push it sideways, it will roll inward but also circle around the center. This is the motion a comet has. If you give the marble or bearing the right push, it will roll around the center in a circular path. A greater push will send it outward, climbing up the slope for a time, then falling back and passing through the point where you started its motion.

Of course, friction between the marble or bearing and the surface tends to slow the motion and the marble falls inward quite rapidly. The heavenly bodies encounter no friction so they do not fall inward. Nevertheless, your model gives you a good idea of the relation between the sideways motion and the type of path followed by a planet or satellite. It also helps to explain how an earth satellite falls rapidly once it encounters friction in the upper atmosphere. If you attach a handle to your model so that you can start a marble rolling from the center by giving a rotary motion to it, you can also see how a satellite can be sent into orbit around the earth. And also with skill you can keep the marble rotating in orbit or give it enough speed to send it beyond the "pull" of the slope of your model, demonstrating escape from gravity.



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29. *Demonstrating the earth's rotation*

You believe that the earth rotates once in 24 hours. But what direct evidence do you have to back up this conclusion? Like the people of ancient times, you see the sun, moon, and stars rise in the east each day. Is there any evidence that the earth rotates rather than that the sky revolves around the earth as the ancient people believed? One observation you can make seems impossible to explain unless the earth is rotating. You can observe the behavior of a Foucault pendulum, a device designed by a French physicist in the nineteenth century.

You will need a fairly heavy, symmetrical bob on the end of a thin wire ten feet or more long. Suspending the bob requires a great deal of care, for the suspension at the top

must act like a point. One way is to take the end of the wire through a securely fixed clamp. If you are handy with tools, you might make a C-shaped device so that the bob can be suspended from the lower point of the C while the upper part, drawn to a sharp point, rests on a smooth metal plate. A fishhook upside down might do. This device keeps the earth's rotation from twisting the pendulum as it swings back and forth.

The swing of the pendulum must be started very smoothly. You can bore a small hole near the edge of the bob, run a thread through it, and tie it to a solid support. Then when you burn the thread with a match, the bob starts its swing.

This model of a Foucault pendulum will swing in one direction while the room seems to rotate around the pendulum. Near the far end of the swing set up two uprights — pencils or nails — which can readily be knocked over. Adjust these so that the pendulum is just swinging between them. The upright on one side will always be knocked over. Which one will it be? How does this provide evidence that the earth rotates?

GOING FURTHER

The projects in this section are by no means all that you can do on your own. They are but a start towards a lifetime hobby or towards a career. The following references should be helpful.

Books

1. *Stars* by Herbert S. Zim and Robert H. Baker, Simon and Schuster, 1951.

2. *Golden Book of Astronomy* by Rose Wyler and Gerald Ames, Simon and Schuster, 1955.

3. *Splendors of the Sky*, from the Sky Publishing Co., Harvard Observatory, Cambridge, Mass. Mainly pictures.

4. *Fun with Astronomy* by Mae and Ira Freeman, Random, 1953.

5. *You Among the Stars* by Herman and Nina Schneider, Scott, 1951.

6. *Sun, Moon, and Stars* by W. T. Skilling and Robert S. Richardson, McGraw, 1946.

7. *New Handbook of the Heavens*, 2nd edition, by Hubert J. Bernhard, Dorothy A. Bennett, and Hugh S. Rice, Mentor, 1950.

8. *Celestial Objects for the Common Telescope* (reprint) by T. R. Webb, Dover, 1959.

9. *Life on Other Worlds* by Harold Spencer Jones, Mentor, 1958.

10. *Discover the Stars*, rev. edition, by G. Johnson and I. Adler, Sentinel, 1957.

Publications

11. *Old Farmer's Almanac*, 25 cents annually. Contains much interesting information on celestial events.

12. *Sky and Telescope*, Harvard Observatory, Cambridge, Mass.

13. *Griffith Observer*, Griffith Observatory, Los Angeles, Calif.

Newspapers sometimes run simple star columns and accompanying star maps.

Miscellaneous

Sources of pictures are the Sky Publishing Company, Harvard Observatory, Cambridge, Mass. (2 Sky sets of 24 large prints at $4.00 per set); the *National Geographic Magazine;* the Hayden Planetarium of the American Museum of Natural History in New York, and the large planetariums in Philadelphia, Chicago, Durham, N.C., Pittsburgh, Los Angeles, San Francisco, and Boston; Yerkes Observatory, Williams Bay, Wis.; Mt. Wilson Observatory, Pasadena, Calif., and Palomar Observatory, California Institute of Technology, Pasadena.

Basic Units of Measurement

Suppose someone told you that Vanguard I, our first satellite, was traveling 120. Wouldn't you ask "120 *what*"? Suppose he said "120 minutes." Would that tell you enough? Not at all. He would need to tell you that Vanguard I circles the earth once every 120 minutes. Then you would know a bit of what he's talking about. You would know two quantities — *time*, and in this case, the approximate *distance*. If he told you the *weight* of Vanguard I, you would know still more. These three units, time, distance, and weight — or *time*, *length*, and *weight* (or better, *mass*, as we shall explain shortly) — are the three basic units in measurement.

Exact definitions of these units are difficult to give but for our purposes we shall define them this way:

Length is the distance between two points. For a circle, this can be the distance from one point to another on the circle. All the way around to the starting point would be the circumference.

Time concerns our sensing of events as they happen one after the other; that is, with their sequence (whether they come before or after). Actually we do not think of time this way but we do think of its measure in hours, minutes, seconds.

Mass is the most difficult to define for our present purposes. Let us think of it as the quantity of matter in a given object, say your pen. For day-to-day purposes, we can say that the weight of a pin, a dime, or a man is the same for each object anywhere on the surface of the earth. We can talk about mass and weight (as they are measured in any part of the United States) interchangeably for our general purposes. Thus you would be quite safe in saying that a turkey weighing 8 pounds that you bought in the market has a mass which is expressed by its weight. Just remember, however, that the scientist uses mass differently from weight, as you will learn later.

HOW WE MEASURE LENGTH

It would be confusing, would it not, if you ordered a foot of platinum wire (quite expensive) from France and found that the French measurement for a foot was different from yours? Actually France does have a different system for measuring length. Clearly we need standard units for measuring length.

The English System

From experience, you can handle our system for measuring length in inches, feet, yards, and miles. The system you use is tabulated below.

1 foot = 12 inches
1 yard = 3 feet
1 mile = 5,280 feet

The English system is widely used in the United States. But the French don't use it — nor the Italians — nor do scientists when they can help it.

The Metric System — Length

$$
\begin{aligned}
1 \text{ meter (m.)} &= \text{length of the standard bar} \\
1 \text{ decimeter (dm.)} &= \frac{1}{10} \text{ of a meter (0.1 meter)} \\
1 \text{ centimeter (cm.)} &= \frac{1}{100} \text{ of a meter (0.01 meter)} \\
1 \text{ millimeter (mm.)} &= \frac{1}{1{,}000} \text{ of a meter (0.001 meter)} \\
1 \text{ kilometer (km.)} &= 1{,}000 \text{ meters} \\
(1 \text{ yard} &= \frac{3{,}600}{3{,}937} \text{ of a meter}) = 0.914 \text{ meter}
\end{aligned}
$$

They use the metric system. Why? Let us see if there are advantages in the metric system.

The Metric System

The unit of the metric system is the meter (ME-ter). Originally, it was set at one ten-millionth of the supposed distance from the equator to the North Pole. As you shall see, a meter is just a bit longer than a yard.

A very durable alloy[1] of platinum and iridium was marked in this length. This meter bar of platinum and iridium is kept under careful laboratory-controlled conditions near Paris. From this meter bar other extremely accurate copies have been made. The bar near Paris is said to be the *standard* bar, and all other meter bars are standardized from it.

[1] An alloy is a combination of two or more metals (see p. 331). In an alloy the metals are generally *not* chemically combined, although exceptions are known. An alloy you are acquainted with is brass, a combination of copper and zinc.

The table shows how the metric system is based on this standard bar, so that scientists may make measurements merely by moving the decimal point to the right or left.

Multiplying and Dividing in the Metric System

Suppose you want to change 52,348 feet into miles. Yes, of course; divide 52,348 by 5,280. But if you want to change 52,638 centimeters into meters, how would you go about doing it?

Simply divide by 100 or move the decimal point two places to the left and you have your answer, 526.38 meters. Refer to the table and you will see why. Yes, a centimeter is $\frac{1}{100}$ of a meter.

The metric system is also used to measure mass, as you will see shortly. Would it not be convenient to have one standard world-wide system which measures length and mass? Scientists use one system, the metric system, the world over. They would like to see it become standard for all purposes.

Changing from One System to the Other

Earlier we spoke of the standard iridium-platinum meter bar that is kept in Paris. How long is it in inches? You will find that

1 meter = 39.37 inches

How many centimeters are equal to 1 inch? Since 1 meter = 39.37 inches and also 100 centimeters, we clearly see that

100 centimeters = 39.37 inches

$$1 \text{ inch} = \frac{100}{39.37} \text{ centimeters}$$

Therefore, 1 inch = 2.54 centimeters.

HOW WE MEASURE MASS

You probably remember the English system of weights, much as you remember the English system of lengths. (Note we used the word *weight* — not *mass*. Remember that for *ordinary purposes* weight is generally interchangeable with mass, at sea level on this planet.) As we have already indicated, for very careful measurements weight and mass are not the same because the same mass will give different weight measurements on the same scales under different conditions. For example, mass is a quantity of material, but weight is the measure of the pull of gravity on this quantity (see Chapter 9). Thus the farther a mass is from the center of the earth, the less the pull of gravity, and hence the less its weight. But we repeat, for the time being, we can measure mass in terms of weight units. The units in the English system are given below:

16 ounces (oz.) = 1 pound (lb.)
2,000 lb. = 1 ton

The Convenient Metric System

Here again scientists find the metric system more convenient. And again, like the iridium-platinum bar

The Metric System — Mass

1 kilogram (kg.) = mass of standard block (mass of water at 4° C. in standard 10 cm. cubic box) = 1,000 grams

1 gram (gm.) $= \frac{1}{1{,}000}$, or (0.001) kg.

1 milligram (mg.) $= \frac{1}{1{,}000}$, or (0.001) gm.

What is the relation of 1 kilogram to 1 pound?
1 kg. = 2.2 lb. (approximate but close enough for our purposes)

How many grams will there be in 2.2 pounds? Yes, 1,000 grams. And how many grams are there in 1 pound?

$$1 \text{ lb.} = \frac{1{,}000 \text{ gm.}}{2.2} = 454 \text{ gm.}$$

whose length is based on a standard of length (1/10,000,000 of the supposed distance between the equator and the North Pole), there is a standard for mass that scientists have devised. It is the *kilogram*. Do you remember what the prefix "kilo" means?

The standard kilogram is derived in this way. A cubic box 10 centimeters at each inside edge is filled with water. The water must be pure and at a temperature of 4 degrees centigrade. The water at 4° C. in a cubic box 10 centimeters at each inside edge weighs 1,000 grams — or 1 kilogram.[1] Standard blocks of metal can be made exactly equal to this mass of water. These blocks weigh exactly the same as the mass of water — 1,000 grams or 1 kilogram. Any mass can be accurately compared with these standard blocks at any place. The table gives the units of weight in the metric system.

HOW WE MEASURE TIME

Have you a watch? What time is it? You have no difficulty with these units — hours, minutes, seconds; you're accustomed to them — and they are world-wide. You may know that the basis for the unit of time is the rotation of the earth; one rotation takes 24 hours, from noon today till noon tomorrow, for example. Actually it is a few minutes less than that, about 23 hours and 56 minutes for one rotation (see p. 151).

Today scientists are able to measure in billionths of a second the speed of the tiniest particles; these particles are parts of an atom. For ordinary measurement of time the regular swing of a pendulum can be counted — such as 60 swings in a minute. It has been found that the particles inside the atom (electrons, protons, neutrons) vibrate regularly, too. So it should not surprise you that more accurate clocks are being developed based on the regular vibrations of atomic particles. These kinds of clocks will be developed for wide use during your lifetime, and they will be extremely accurate.

HOW WE MEASURE VOLUME

It is often very useful to know the volume of an object, which can be derived from units of length. You've already measured length with a ruler and even area (which is length × width).

Volume is the amount of space an object occupies. You have already used the measure of volume in order to determine the mass of a standard kilogram. You merely multiplied the *length* by the *width* by the *height*.

Suppose you want to measure the volume of your car battery. You find it is 10 inches long by 8 inches high by 6 inches wide. How do you find the result? Easy, you say:

$$\begin{aligned}\text{Volume} &= \text{length} \times \text{width} \times \text{height}\\ &= 10 \times 6 \times 8 = 480 \text{ cu. in.}\\ &\qquad (\text{or in.}^3)\end{aligned}$$

Or, as soon as you buy your own home, you will find that both the heating system you install and the bill for heating the house are based on the *cubic feet* (the volume) of the house. You will measure the *length,*

[1] Put another way, 1 cubic centimeter of water at 4° C. weighs 1 gram.

width, and *height* of the rooms in feet to get the cubic feet (cu. ft. or $ft.^3$).

Or, you may have read in Chapter 4 that a cubic centimeter of blood has almost 5,000,000 red blood cells and 7,000 white blood cells. This would mean that a drop which would fit into a box 1 centimeter (cm.) long, 1 centimeter wide, 1 centimeter deep on the inside would have the number of cells above.

Let us review volume and then compare the units for measuring volume in the English and metric systems.

In measuring mass (p. 651), we multiplied the sides in centimeters 3 times. Really we measured *three* lengths (although we called them length, width, and height). We might say the formula for measuring a cube is L^3, or in this case, cm^3.

In measuring the volume of our battery we had three different lengths which we multiplied together, but the result is still in cubic measurement; in that example, in^3. We can also have measurement in cubic feet ($ft.^3$), or cubic yards ($yd.^3$).

Scientists use the metric system to describe volume as well as length and mass. Thus, as you have seen, they use the cubic centimeter, which is a box 1 centimeter in length on each edge. The abbreviation for a cubic centimeter is cc. or ml. (milliliter — one thousandth of a liter) for liquid measurement; or, as you learned earlier, $cm.^3$, for measuring solid objects.

VOLUME IN THE ENGLISH AND METRIC SYSTEMS

1,000 cc. = 1.1 quarts (qt.)
1,000 cc. = 1 liter (l.)
The liter is then 1.1 quarts.
32 oz. = 1 qt.
1 oz. = 28.4 cc.

HOW WE MEASURE VELOCITY

It would be easy if everything you were going to measure in your life required using just length, time, or mass (weight). Actually you use many combinations of units.

Scientists and others who use accurate measurement *derive many units from* the fundamental ones we've discussed. We've already derived one unit, *volume*, from the fundamental unit, *length.*

As soon as you begin to drive a car — and you soon will — you will use a unit derived from *time* and *length*, two of the fundamental units. This unit is *velocity.*

You will see signs along the road that say: "Speed limit 50 miles per hour." Notice that *length* (miles) and *time* (hours) — two units — have been combined into a new *single* or derived unit, *velocity* (speed). It just wouldn't do to say, "Speed limit is 50 miles" — unless the unit of time is also understood.

Let us see how you could measure the velocity of a car. How does a policeman do it to determine when the speed limit is exceeded?

The traffic policeman (usually on a motorcycle) would measure the length of a strip of the road and use a stop watch to time the cars as they speeded over this measured distance. Actually he uses a formula such as this one:

Velocity = distance per *unit of time*

What does *per* mean? Per means the same as "divided by." So

$$\text{Velocity} = \frac{\text{distance}}{\text{time}}, \text{ or } \left(v = \frac{d}{t}\right)$$

Thus if your car traveled 1,000 feet in 20 seconds, your velocity would be

$$\text{Velocity} = \frac{1{,}000 \text{ ft.}}{20 \text{ sec.}} = 50 \text{ ft./sec.}$$

or 50 feet per second, since the slanting line (/) means per.

You now have developed or derived a unit, velocity. It is measured in feet/second or miles/hour. These are not really new units; you've been using them all along in your everyday life. Here are some statements using the units:

1. Vanguard I, one of our space satellites, travels at a velocity of 20,000 miles per hour.
2. A jet plane broke the sound barrier (see p. 520). It traveled faster than 700 feet/second — the speed of sound.
3. A cold front (a mass of cold air) may travel eastward at the rate of about 20 miles/hour.

Look for other statements that use this derived unit, velocity.

ACCURACY — SIGNIFICANT FIGURES

Measuring instruments are tools of the scientist because many observations must be very exact — more exact than his observations made by his senses and interpreted by his brain alone can measure. In talking with others — scientists, or engineers, or the general public — he needs to be able to answer questions like "How much? How long? How far? How thick?" Thus he develops standard units so that an experiment or a process can be understood, or a machine can be put together in exactly the same way. As you saw on p. 14 observation by senses alone, unaided by accurate instruments, is generally not enough.

But just understanding how measurement is done and the meaning of such units as we have discussed — time, velocity, volume, weight, mass — is not enough. Measurement must be expressed accurately in significant numbers. Let's find out the meaning of "significance" with regard to the following numbers (as used in measurement).

The mass of the sun is estimated to be about 2,200,000,000,000,000,000,000,000,000 tons.

How *significant* (how meaningful) would it be to say the mass of the sun is about 2,200,000,000,000,000,000,000,000,000.1 tons?

Does the 0.1 of a ton add much to the measurement if the word "about" precedes the figure? Obviously not. The 0.1 is not significant — that is, it has no meaning because we don't have an instrument that is accurate enough to weigh the sun as accurately as this — to 0.1 of a ton.

The figure must be as useful as the *operation* by which it was obtained. For instance, would you measure a carpet in feet and inches or in millimeters? Clearly feet and inches are sufficient. Measuring a carpet in millimeters is like swatting a fly with a sledge hammer. You would be trying to be too accurate for your purposes.

Once you have measured a quantity — say a length, a volume, or a weight — how do you express it in numbers?

The accuracy of a measurement is shown by the number of digits (0, 1, 2, 3, 4, 5, etc.) you note. In determining the accuracy of your measurement you do not count the zeros

needed to locate the decimal point. Thus when you write "length = 15 centimeters," it means that you have measured the object to the *nearest centimeter*. Your measurement might have been 15.1, 15.2, or 15.3 centimeters, but for the purposes of your measurement you thought it accurate enough to measure only to the nearest centimeter — *not to the nearest tenth of a centimeter* (as expressed by 15.1 cm. or 15.2 cm.). However, a measure of 15.3 cm. is a measurement to the nearest tenth of a centimeter.

Do you see that 15.3 cm. is a more accurate measurement than is 15 cm.? Do you see that it took more care to get a measurement of 15.3 cm., than to get one of 15 cm. on the same object? Since the measurement is more accurate, the figure is expressed more accurately in 3 *significant* figures: *15.1* cm.; it is more accurately expressed than in 2 significant figures: *15* cm.

If you had written 15.0 it would have meant that you had measured to the three significant figures, to the nearest tenth of a centimeter; the .0 would be a *significant* figure. Thus you express your measurements in the number of figures which indicate the precision, the accuracy, of your measurement.

This means that you should never write 51 cm. as your measurement when your measurement was accurate to the nearest tenth; this should be written 51.0. Similarly, 51.03 would mean that you had measured the length to a hundredth of a centimeter — and the four figures are significant.

The number of significant figures is the number of digits that serves the purpose for which the measurement was made. Usually when you measure length in meters or weight in grams, a notation of three significant figures is sufficiently accurate. That is, 249, 24.9, 2.49, or 0.249 meters. All of these are accurate to three significant figures; in each case you are merely measuring shorter lengths.

Usually, in doing problems involving measurement in the school laboratory, your teacher will indicate the number of significant figures he desires. Whether you measure to one or two decimal points — or none — will depend on the purpose of your measurement and on how accurate is the instrument you are using.

FOR YOUR READING AND RESEARCH

All science depends on accurate measurement; but several measurements are of exceeding interest. Possibly you will want to read how these measurements have been obtained. We will give you, as a lead to your research, the fields of work in which the measurements were done. We would like you to get practice in searching out the way these measurements were made. Four of these are in this text. Two are advanced work and are not included in this text. One is a project for you to determine by yourself.

1. *The measurement of the speed of light* (physics).
2. *The age of the earth* (biology and geology).
3. *The weight of a liter of air* (meteorology).
4. *The weight of a liter of hydrogen* (chemistry).
5. *The weight of an atom of oxygen* (chemistry).
6. *The weight of an electron* (physics).

7. *The amount of carbon dioxide in a liter of exhaled air* (biology). This is a project for you to determine.

Remember, you will find brief descriptions in this text of how four of these were made. A clue to how to do your own project (7) is on pp. 60 and 93. For the others you will have to hunt out a book in the field mentioned. Try your home or school library and the public library.

The Vocabulary of Science — A Glossary

absorption: the passing of digested food through the walls of the villi in the small intestine into the surrounding lymph or blood

acceleration (ak-sel-uh-RAY-shun): the change in speed when anything is made to go faster

accommodation: the change in shape of the lens of the eye so that a person can see things both near and far

acoustics (uh-KOO-stiks): the science dealing with the study of sound

acquired trait: a characteristic which is not inherited (or inborn) but is developed during the life of a plant or animal

adaptation: having the body structures and body activities necessary to live in a certain environment

aeration (AY-er-ay-shun): supplying with air

aerial: *See* antenna

aileron (AY-ler-on): a flap set in the edge of the wings of an airplane to control its course

air conditioning: a system of controlling the temperature, pressure, and humidity of air entering a room

air mass: a large body of air having the same temperature, pressure, and humidity

alloy (AL-oi): a substance composed of two or more metals; for example, bronze

alternating current: an electric current that changes its direction in regular cycles

altimeter (al-TIM-uh-ter): an instrument used to measure height above the earth's surface

ampere (AM-peer): the amount of electrons that pass a given point in an electric conductor (for example, a wire) in 1 second; the unit for measuring the strength of an electric current

amphibian (am-FIB-ee-un): one of a class of vertebrates, including frogs and toads, that pass through a stage in which they live in water and have gills; later, when these vertebrates move to land, the gills are replaced by lungs

amplifier (AM-plih-fy-er): a device in a radio set that makes weak electric currents stronger

amplitude (AM-plih-tood): refers to the height of a wave (for instance, a sound wave) produced by a vibrating object

amplitude modulation (AM): in radio, the process of modifying the carrier wave by varying its amplitude; the conventional method in most radio broadcasting

anemia (uh-NEE-mee-uh): a disease caused by lack of iron or not enough red blood cells in the blood, or not enough hemoglobin

anemometer (an-uh-MOM-uh-ter): an instrument used for measuring the force or speed of the wind

aneroid (AN-er-oyd) **barometer:** a type of barometer which does not use mercury or any other liquid; the metal can in which there is a partial vacuum reacts to changes in pressure

angle of attack: the angle of an airplane's wing as it pushes against air

annular (an-YOO-ler) **eclipse:** an eclipse in which a ring of the sun appears around the black disk of the moon

anopheles (an-OFF-uh-leez) **mosquito:** a mosquito that carries the protozoan parasite that causes malaria

antenna: a wire or wires for transmitting or receiving electromagnetic waves

anther: the part of the flower in which the pollen is produced

antibiotic (an-tee-by-OT-ik): any substance that destroys germs and is made by living organisms, such as fungus *Penicillium*

antibody: a substance, usually in the blood of an organism, which serves to counteract the effects of disease-producing bacteria

antiseptic: a substance that opposes the activity of germs

antitoxin: any substance in the body that neutralizes toxins produced by bacteria

aorta (AY-or-tuh): the great artery which carries blood from the heart to all the body except the lungs

apogee (AP-uh-jee): the position of an earth satellite at the point in its orbit when it is farthest from the earth

appendix: a wormlike, narrow tube, about 3 or 4 inches long, in the lower righthand part of the abdomen

Archimedes' (ahr-kih-MEE-deez) **principle:**

a law which states that an object, when placed in a liquid, is buoyed upward by a force equal to the weight of the liquid displaced by the object

armature (AHR-muh-cher): a piece of metal or a coil of wire that moves back and forth, or rotates, in a magnetic field

artery: one of the blood vessels which carry blood from the heart through the body

artesian (ar-TEE-zhun) **well:** a well, drilled through rock layers, from which water flows upward under pressure

ascorbic (as-KOR-bik) **acid:** vitamin C, found in citrus fruits, tomatoes, and green vegetables

asexual (ay-SEK-shoo-ul) **reproduction:** producing offspring as a result of the division of parent cells one at a time

asteroid (AS-ter-oyd): one of a group of small planets between Mars and Jupiter, of which about 1,500 have been listed; estimated number runs to 30,000 or more

atmosphere: the whole mass of air surrounding the earth

atom: the smallest particle of an element that has properties of that element

atomic fission: the breaking down of an atom, especially its nucleus, into two or more parts, with a great release of energy

atomic fusion: the joining of deuterium (heavy hydrogen) and tritium (another form of heavy hydrogen) to make helium

atomic pile: a mass of uranium rods, imbedded in pure carbon, that produces a chain reaction and releases atomic energy

atomic weight: the weight of an atom of any element compared with the weight of an atom of oxygen, which is set at 16

aureomycin (or-ih-oh-MY-sin): a chemical produced by certain soil bacteria, useful against infection in the human body

auricle: a chamber of the heart which receives blood from the veins

axis: an imaginary line through the earth's poles

bacillus (buh-SIL-us) (pl., bacilli): any of the straight, rod-shaped bacteria

bacteria: microscopic, one-celled organisms depending on living or dead food material; many cause disease; some are helpful

balance in nature: the interdependence of all plants and animals with their environment

barograph (BAIR-uh-graf): an instrument which measures changes in air pressure and records them on a graph

barometer (buh-ROM-uh-ter): an instrument for measuring air pressure

behavior: the way a living thing acts

beriberi (BEHR-ee-BEHR-ee): a disease caused by a diet lacking vitamin B_1 (thiamine)

bile: a greenish fluid which is secreted by the liver and passes into the small intestine, where it aids in the digestion of fats

bladder: a part of the body that is a sac, holding a liquid such as bile or urine

blast furnace: a furnace in which pig iron is made from iron ore

blood transfusion: the transferring of the blood from one person to another

brain: the main center of the human nervous system, made up of a cerebrum, cerebellum, and medulla

breeder reactor: a nuclear reactor in which more atomic fuel is made than is used up

bronchial (BRONK-ee-ul) **tube:** one of the two branches of the windpipe that divide again and again, finally ending in a group of thin-walled air sacs

cadmium: a white metal that is used to control the flow of neutrons in an atomic pile

calcium: a silvery-white, soft metal; in compounds it is useful in the growth of bones

calorie: the amount of heat needed to raise the temperature of 1 gram of water 1 degree centigrade (a large calorie is 1,000 small calories). Large calories are used in measuring food diets

cancer: an abnormal, harmful growth of cells

capacitor: another term for condenser

capillary (KAP-'l-air-ee): a thin-walled tube; one of the tiny blood vessels in the network connecting the arteries and the veins

carbohydrate: a compound, such as sugar or starch, made up of carbon, hydrogen, and oxygen

carbon dioxide: a heavy, colorless gas which is a result of burning of food

carbon monoxide: a colorless, odorless, poisonous gas formed when gasoline does not burn completely in a gasoline engine; a part of illuminating gas (cooking gas)

carnivores (KAHR-nih-vohrs): the flesh-eating animals

carrier wave: a radio wave that carries a

broadcast from the transmitting antenna to the aerial of a radio receiver

cartilage: an elastic, yet hard, tissue composing most of the skeleton of the very young of all vertebrates; found in the ear, nose, and breastbone of adults

cast iron: brittle iron that is usually cast in molds

cell: the smallest microscopic body of which a many-celled living thing is made; it has a nucleus, cytoplasm, and a cell membrane

cell membrane: the thin outer layer of cytoplasm acting as a cell boundary

cement: a mixture of clay and limestone used in making concrete for building

centigrade thermometer: a thermometer that has 100 degrees or divisions between the freezing and boiling points of water; 0° C. is the freezing point, and 100° C. is the boiling point

central heating: a method of heating an entire building from one central furnace, usually located in the basement

cerebellum (ser-uh-BEL-um): the part of the brain controlling balance and the movement of muscles

cerebrum (SEH-ruh-brum): the part of the brain concerned with thought and judgment

chain reaction: the reaction in which the splitting of one atom causes other atoms to undergo fission

chemical change: a reaction during which substances lose their identity and change their composition; energy changes always take place during a chemical reaction

chemistry: the science that deals with the make-up of substances and how they are changed into other substances

chlorination: the treatment of water with chlorine to kill germs

chlorophyll (KLOR-uh-fil): a substance that enables green plants to make glucose

chloroplast (KLOR-uh-plast): a small green body which contains chlorophyll, located in the cytoplasm of a plant cell

chromium: a grayish-white, metallic element used in making alloys and in plating metals

chromosome (KROH-muh-sohm): one of the small, generally rod-shaped, bodies found in a cell nucleus; it contains the genes which transmit hereditary traits

circulatory system: of or relating to circulation, as of the blood through the body

cirrus (SIH-rus) **cloud:** a white, filmy type of cloud, usually formed at altitudes of 20,000 to 40,000 feet, generally consisting of ice crystals

clay: finely ground quartz, feldspar, and mica; a result of the erosion of rocks

cloud chamber: an instrument used to trace the paths of atomic particles

clutch: a device that engages or disengages the transmission from the engine of an automobile

coccus (KOK-us) (pl., cocci): a spherical bacterium

cochlea (KOK-lee-uh): a coil-like structure in the inner ear which helps in distinguishing sounds

cold front: the boundary between a mass of advancing cool air and a mass of warm air

comet: a heavenly body with a head and tail, traveling in a long, oval orbit; for example, Halley's comet

communicable (kuh-MYOO-nih-kuh-b'l) **disease:** disease which may be transmitted from one person to another

compound: a substance composed of two or more elements chemically united

concave (kon-KAYV) **lens:** a lens which makes light rays spread apart

conclusion: a judgment reached after studying the result of an experiment

concrete: a mixture of sand or gravel with cement and water, which becomes hard when allowed to dry

condensation: the process of forming a liquid or solid from a vapor or gas

condenser: a device for the storage of electrical energy

conditioned reflex: an acquired automatic act, a result of modifying a reflex

conduction: the transmission of heat through a substance by the rapid movement of its molecules

conductor: a material, such as a copper wire, which carries a flow of electrons (electricity)

conservation: the wise and careful use of our natural resources

constellation: any one of the 88 groups of stars and the area of the sky in its vicinity to which a definite name has been given; for example, Ursa Major, the Great Bear

contact poison: a chemical which kills insects as it comes in contact with their bodies; used especially to kill insects with sucking mouth parts

contour (KON-toor) **plowing:** plowing which

follows the shape or outlines of hilly land, rather than going up the side of the hill

control column: the "stick" a pilot of an airplane uses to help control the direction of the flight of the plane

control experiment: an experiment to check the results of another experiment

convection current: the circulation of air as warm air moves upward and cool air moves in to replace it

convex (KON-veks) **lens:** a lens which makes light rays come together at a point called the focus

cornea (KOR-nee-uh): the transparent tissue in front of the iris and the pupil of the eye

corona: a bright white light which appears to surround the sun when the sun is totally eclipsed by the moon

corpuscles (KOR-pus-'lz): red cells, found in the blood, which have no nucleus, and which are made in bone marrow

cosmic ray: a ray that seems to come from beyond the earth's atmosphere and is made up in part of particles that move with the speed of light

cracking: a process by which the petroleum oils of different boiling points are separated from one another and from other petroleum compounds; used in making gasoline

critical mass: a mass of uranium 235 or other fissionable element of sufficient size to cause an atomic explosion

cross-pollination: the carrying of pollen from the stamen of one flower to the stigma of another, as by insects, wind, or birds. *See* stamen *and* stigma

cumulus (KYOOM-yoo-lus) **cloud:** a type of cloud between 5,000 and 15,000 feet above the earth, having a flat base and rounded masses piled up like mountains

current electricity: the flow of electricity through a conductor, measured in terms of amperes

cutting: any cut portion (leaf, stem, or root) of a plant used for asexual reproduction

cycle: one full wave, such as a radio wave

cyclone: winds blowing counterclockwise about a nearly circular region of low air pressure in the Northern Hemisphere over an area covering thousands of square miles

cyclotron (SYKE-luh-tron): an instrument used to study the properties of atoms by increasing the speed of atomic particles

cytoplasm (SY-toh-plazm): the fluid part of a cell surrounding and outside the nucleus

Dacron: a man-made fiber that resists wrinkling when woven into cloth

Daphnia: a small water flea about the size of a pinhead

data (DAY-tuh): facts from which one or more conclusions may be drawn

DDT: an insecticide used to kill mosquitoes, fleas, and flies

deceleration: the change in speed when anything is made to go more slowly

deficiency (deh-FISH-un-see) **disease:** a disease caused by a lack of vitamins, minerals, or other needed nutrient substances

dehydration (dee-hy-DRAY-shun): the loss of water

delta: a deposit of soil at the mouth of a river

depleted (deh-PLEET-id) **soil:** soil that has lost minerals that plants need for growth

detector: a device for detecting the presence of high-frequency waves, as in radio

deuterium (DYOO-teer-ee-um): heavy hydrogen, with an atomic weight of 2

dew: moisture condensed on the surfaces of cool bodies, especially at night

diameter: the distance from one side of a round object to the other side, measured through the center

diaphragm (DY-uh-fram): a sheet of muscle which separates the chest cavity from the abdomen and by its movement helps in breathing; the name also used for the vibrating disk of metal in a telephone

Diesel engine: a form of internal-combustion engine, using heavy oil instead of gasoline as fuel

differential (dif-uh-REN-shul) **gears:** an arrangement of gears in the rear axle of an automobile which allows one of the wheels to go faster than the other, as in going around curves

diffused light: light reflected from a dull surface and scattered in many directions, thus reducing glare

diffusion (dif-YOO-sh'n): the process whereby the molecules of substances tend to intermingle, as when two gases or solutions are brought into contact

digestive system: the system for breaking down complex foods to simpler ones within the body so that they can pass through the walls of the intestine

direct current: an electric current flowing in one direction only (as contrasted with alternating current)

distillation (dis-tih-LAY-sh'n): the process

of heating a substance until it turns into a gas, and of condensing this gas by cooling

doldrums (DOL-dr'mz): a belt of calms near the equator

dominant trait: an inherited characteristic which always appears when genes for it are present in the individual; for example, tallness of the pea plant, dark hair in man

dormant: inactive or not growing; said especially of buds and seeds during the winter

drag: the force exerted to reduce the forward motion of an airplane

dry cell: a sealed cell in which a carbon rod, manganese dioxide, ammonium chloride, water, and zinc react chemically to produce an electric current

dynamo: a mechanical device used to produce an electric current by rotating an armature coil in a magnetic field

eardrum: a thin tissue in the ear which vibrates as sounds strike it

earthworm: one of the many kinds of worms found in moist soil

eclipse, lunar: the passing of the moon into the shadow cast by the earth; **solar:** the passing of the earth into the shadow cast by the moon; **total:** the complete hiding of one heavenly body by another or by the umbra of the shadow cast by another

efficiency: the amount of useful work done by a machine compared with the work put into it in the same time

egg: a female sex cell which may be fertilized by a sperm

electric circuit: a complete path in which electricity travels from its source out into a wire and back to its source

electric current: a flow of electrons from one place to another

electric meter: a device which measures electric energy; for example, the electric meter which registers in kilowatt-hours the amount of electricity used

electric motor: a device that transforms electric energy into mechanical work; it is made up of a powerful field magnet, between the poles of which an armature made of many coils of wire carrying an electric current is caused to rotate

electromagnet: a core of soft iron surrounded by a coil of wire through which an electric current passes, thus magnetizing the core

electron (eh-LEK-tron): a negative particle revolving about the nucleus of an atom

electron gun: a device in the tube of a television camera or receiver which sends a stream of electrons against the screen of the tube

electron microscope: a microscope that uses a beam of electrons to enlarge a very small object to a great size

electroplating: the process by which electricity is used to transfer metal from a positive pole to the object to be plated (negative pole)

element: a substance that cannot be divided into units different from itself by ordinary means; for example, oxygen, iron

elevator: the movable part of an airplane, attached to the stabilizer; when it is moved upward, the plane climbs; when moved downward, the plane dives

embryo (EM-bree-oh): a living thing in the early stages of development

energy: the capacity to do work

energy of motion: energy that an object has because it is moving; called kinetic energy

environment: the surrounding conditions in which organisms live

enzyme (EN-zyme): a substance in the saliva, stomach, or intestine which breaks down nutrients into simple chemicals; it speeds up the reaction of chemicals without itself being changed

epidermis (ep-ih-DER-mis): the outer layer of an animal's skin

equinox (EEK-wih-noks): a moment, occurring twice each year on or about March 21 and September 23, when the sun appears to cross an imaginary line called the celestial equator

erosion: the act of wearing down and carrying away, as land by the action of wind or water

Eustachian (yoo-STAY-kee-un) **tube:** an air tube leading from the back of the mouth to the cavity of the middle ear

evaporation (eh-vap-uh-RAY-shun): the process of changing a liquid into a gas

excrete: to separate wastes from the body cells or tissues

exhale: the act of breathing air out of the lungs

exhaust stroke: the stroke of an engine in which the piston pushes the burned gases out of the cylinder

exponent: a small figure indicating the

number of times a number is multiplied by itself, as in 10^3.

external-combustion engine: an engine in which the fuel is burned outside the engine

Fahrenheit thermometer: a thermometer graduated so that the freezing point of water is at 32° above zero, the boiling point at 212° above zero

fall-out: radioactive particles that fall to earth as the result of an atomic or hydrogen bomb explosion

farsightedness: a defect of the eye which forms sharper images of things at a distance than of things nearby

fat: a substance deposited in special cells, called fat cells; it is also a nutrient found in foods, used by the body as a source of energy

fault: a dislocation in the earth caused by the slipping of rock masses along a crack

fertilization: the union of a male sex cell (or sperm) with a female sex cell (or egg)

fertilizer: material added to soil to restore its minerals and organic matter

fibrin: a substance formed from fibrinogen when a blood vessel is cut; it forms a covering or clot over the wound

fibrinogen (fy-BRIN-oh-jen): the part of blood plasma that helps to clot the blood

filament: the fine wire inside an electric light bulb that gives off light and heat when electricity is passed through it

filter: a device in electricity which prevents the flow of some frequencies while permitting the passage of others

filtration beds: layers of sand and gravel which catch soil and other particles as water passes through

fluorescent: an object is said to be fluorescent when it gives off light when struck by electrons or by visible or ultraviolet light; a television screen is fluorescent, because its phosphors are struck by electrons

focus: the point at which light rays are brought together (or seem to be brought together) by a lens or mirror

fog: a cloud of condensed water vapor formed on or near the ground

food chain: a number of kinds of living things depending upon one another for food; for instance, herons feed on fish, which feed on snails, etc.

foot-pound: a measurement of work done by multiplying the number of feet an object is moved by the weight (in pounds) of the object

force: a push or a pull on an object

frequency: the number of waves per second; for example, sound waves, radio waves

frequency modulation (FM): in radio, the process of modifying the carrier wave by varying its frequency; the resulting signal is less affected by static than is the more conventional amplitude-modulated (AM) signal

friction: the resistance of two surfaces sliding over one another

front: the boundary region where one mass of air meets another of a different type

frost: a deposit of ice crystals which forms on objects that are colder than the freezing point of water

fulcrum: the point of rest upon which a lever turns in moving an object

fungus (FUNG-gus): a plant of simple structure which lacks chlorophyll and therefore cannot make its own food; for example, bread mold, *Penicillium*

fuse: a device to break an electric circuit that is overloaded

fuselage (FYOO-z'l-ij): the body of an airplane which holds the engine, passengers, cargo, etc., and to which are attached the wings, tail, and landing gear

g: the pull of gravity. (17 *g*'s = 17 times the pull of gravity.)

galaxy (GAL-uks-ee): a star system or cluster of stars; for example, the Milky Way

galvanize (GAL-vuh-nyz): to coat iron with zinc to protect the surface of the iron

gamma globulin: a material in blood plasma which is thought to protect against polio

gamma rays: rays similar to X rays given off by exploding atoms

gas: an airlike substance having no independent shape or volume, but able to expand to the shape of its container

gasoline engine: an internal-combustion engine which uses the heat energy of gasoline for its operation

gastric (GASS-trik) **juice:** the acid digestive fluid given off by the glands in the walls of the stomach

Geiger counter: an instrument that detects the presence of radioactive material by giving off clicks when radioactive particles strike its tube

gene (JEEN): one of the particles of the

chromosome which transmits hereditary traits

generator: a machine that changes mechanical energy into electrical energy by cutting magnetic lines of force with coils of wire

germ: any one of the harmful bacteria, viruses, or protozoa

gland: a part of the body which makes secretions such as enzymes or hormones

glucose (GLOO-kohss): a simple, soluble sugar oxidized in the body to give energy

goiter: an enlargement of the thyroid gland

grafting: joining the cut branch of one plant to that of a rooted plant which supplies water and minerals

gravity: the force that holds everything to the earth; the attraction between any two masses of matter

gullet: the tube by which food and drink swallowed pass to the stomach

habit: a learned, automatic act

hard coal: coal that gives off a great deal of heat, leaving little ash (anthracite coal)

hard water: water containing a large quantity of dissolved mineral salts

heavy water: water in which the hydrogen is twice as heavy as in ordinary water

hemoglobin (HEE-moh-gloh-bin): the iron-containing red substance found in the red blood cells; it carries oxygen

herbivores (HER-bih-vohrs): plant-eating animals

heredity: the transmission of characteristics through the parents to the offspring

hibernation (hy-ber-NAY-shun): the act of sleeping throughout some or all of the winter season

hormones (HOR-mohnz): substances (produced by glands) carried by the blood, having a great deal to do with height, weight, bone growth, and even behavior

horse latitudes: two areas of light winds in the region of 35 degrees north and 35 degrees south latitude

horsepower: a unit for measuring rate of work, equal to 550 foot-pounds per second

host: a plant or animal on which a fungus grows

humidifier: a device used to add moisture to indoor air

humidity: refers to the amount of water vapor in the air

humus (HYOO-mus): a brown or black material in the soil formed by decay of dead plants and animals or parts of them (leaves, etc.)

hurricane: a wind of 75 miles an hour or more, usually starting as a tropical cyclone

hybrid: the offspring of two animals or plants of different races, kinds, or species

hydrochloric acid: an acid produced in the stomach which, with the help of pepsin, breaks down proteins into simpler substances

hydrogen bomb: a bomb consisting of deuterium and tritium (forms of heavy hydrogen) which are fused into helium. This fusion is the cause of the tremendous energy given off by the H-bomb

hypothesis (hy-POTH-uh-siss): an idea (a working idea) not yet proved and depending upon further facts for its proof

IGY: the abbreviation for the International Geophysical Year, an 18-month period from July 1, 1957, to December 31, 1958, and now extended indefinitely as the IGC, or the International Geophysical Cooperation

image: a likeness of a person or object which can be seen in a picture or on a screen, as in photography or television

image-orthicon (OR-thih-kon) **tube:** a special type of radio tube used in a television camera to change an image or picture into a current of electricity

immunity: protection against a disease

impulse: that which travels along nerve cells or fibers

inbreeding: the mating of closely related organisms, such as self-fertilized plants

inclined plane: a sloping plane that makes an angle with a horizontal surface

inertia: the property of a body at rest remaining at rest, or a body in motion remaining in motion

infrared rays: rays just longer than those of visible red light; sometimes called heat rays

inhale: the act of breathing air into the lungs

inherited trait: a trait that is received from an ancestor

inoculation (in-ok-yoo-LAY-shun): introduction (under the skin) of a vaccine or an antitoxin to produce immunity

insulation: any material used to reduce the transfer of heat or to shield a conductor of electricity

insulin (IN-suh-lin): a secretion from the pancreas which is used in the control of diabetes

internal-combustion engine: an engine in which the fuel is burned inside the cylinders

international date line: a map boundary (drawn to avoid all land areas) between west and east longitude, which lies on or near the 180th meridian

intestine: a section of the digestive system (below the stomach) in which digestion and absorption of substances take place

invertebrate: an animal having no backbone

iodine: an element occurring ordinarily as a blackish-gray crystalline solid obtained from ashes of seaweed; used to prevent goiter and the enlargement of the thyroid gland

ionosphere (eye-ON-uh-sfeer): the highest region of the atmosphere, which is beginning to be explored by means of high-altitude rockets

iris (EYE-riss): the doughnut-shaped muscular screen of the eye, usually colored, which surrounds the pupil

irrigation (ih-ruh-GAY-sh'n): supplying land with water by means of canals and ditches

isobar (EYE-soh-bahr): a line on a weather map connecting observatories reporting the same barometric pressure

isotherm (EYE-soh-therm): a line on a weather map connecting observatories reporting the same temperature; usually only the 0° F. and 32° F. isotherms are shown

kidney: one of a pair of bean-shaped glands, in the back part of the abdomen near the spinal column, that collect the wastes which form the urine, which then passes to the bladder

kilocycle (KIL-uh-sy-k'l): one thousand waves, such as radio waves

kilowatt-hour: a unit of energy equivalent to 1,000 watts of electric power used in 1 hour

kindling temperature: the temperature to which a fuel must be raised before it will burst into flame

Kinescope (KIN-eh-skohp): a cathode-ray tube used in a television receiver to reproduce the image

kinetic (kin-NET-ik) **energy:** energy of motion

Kingston valve: a valve in a submarine that when open allows water to rush into the ballast tank

lacteal (lak-TEE-ul): one of the small vessels in the villi of the small intestine which absorb digested fats

larva (LAHR-vuh): the young of some animals, especially insects; for example, the grub of a beetle or the caterpillar of a moth

larynx (LAIR-inks): that section of the upper part of the windpipe in which the vocal cords are found

latitude: the distance due north or south from the equator, measured in degrees and marked by an imaginary line parallel to the equator

layering: a method of reproduction of plants (asexual reproduction) in which a stem is turned back into the soil and grows new roots, stems, and leaves

legume (LEG-yoom): a member of the pea family; for example, peas, beans, clover, alfalfa

lever: a bar used to move some object with the use of a fulcrum

lift: air pressure under the wing of a plane

lightning: an electric discharge between two clouds, between a cloud and the earth, or between two parts of the same cloud

lightning rod: a large metal conductor used to carry electrons safely to the ground and thus prevent damage to property by lightning

light-year: the distance which light, traveling at about 186,000 miles each second, travels in one year

lines of force: lines in a field of force of any magnet that show the amount and direction of the field

liquid: any substance that flows more or less freely, such as water

liquid air: air that has been made into a liquid by cooling it to −312° F.

liver: a large organ that secretes bile and causes important changes in the blood

loadstone: a natural rock magnet occurring in the earth

loam: ordinary garden soil, a loose soil made up mainly of clay and sand and a small amount of humus

longitude (LON-jih-tood): distance on the earth's surface measured in degrees east or west of the meridian of Greenwich

low: an area of low air pressure (in the center of a cyclone or hurricane)

lymph (LIMF): a nearly colorless fluid, chiefly blood plasma, found in lymphatic vessels

machine: any device which transmits force and energy to do work

magnetic field: an area in the vicinity of

a magnet or an electric current in which magnetic lines of force can be noted

magnetism: the property of attracting, which loadstone, iron, and some other substances possess

malaria: a disease in which the symptoms are chills followed by high fever and sweating (caused by a protozoon carried by the anopheles mosquito)

mammal: one of the class of vertebrates that suckle their young

matter: any substance that occupies space

maximum-minimum thermometer: an instrument used by weathermen to denote the highest and the lowest temperature within a given time

medulla (meh-DUHL-uh): the part of the brain concerned with breathing and heartbeat

megacycle (MEG-uh-sy-k'l): one million waves, such as radio waves

membrane: a thin, soft sheet of animal or plant tissue; also the outer edge of the cytoplasm of every living cell

meridian: a line running north and south on a map, numbered according to its degree of longitude

meteor (MEE-tee-er): a heavenly body which glows for a moment as it passes through the atmosphere; a "shooting star"

meteorite (MEE-tee-er-eyt): a meteor that has struck the earth's surface

meteoroid (MEE-tee-er-oyd): a small, dark object passing through space but yet not within the earth's atmosphere

methane (METH-ayn): a colorless, odorless, flammable gas; "fire damp" of coal mines

microbe: a very tiny plant or animal; a bacterium, especially of a disease-producing kind

micro-organism: any organism of microscopic (or smaller) size

migration (my-GRAY-shun): a movement of organisms from one area to another, usually a mass movement

mineral: any chemical element or compound occurring free or in rocks

mixture: two or more substances mixed together in no definite proportions and not chemically united; air is a mixture, but pure water is a compound

modulation: *See* amplitude modulation *and* frequency modulation

mold: a fungus; for example, bread mold; fungi have no chlorophyll

molecule: the smallest part of any substance that has the properties of that substance

mucous membrane: a tissue of flat cells lining the cheek, gullet, stomach, and intestines

mutant (MYOO-tant): an animal or plant which differs from the parents in having one or more new traits which can be inherited

mutation: a sudden change or variation caused by a change in some of the contents of the nucleus of a sperm or egg

natural immunity: natural resistance to a disease

neap tide: the lowest high tide and the highest low tide between spring tides

nearsightedness: a defect of the eye which forms sharper images of things nearby than of things at a distance

negative (photographic): a photographic film in which the lights and shades, and the relation of right and left, of the original are reversed

neon: an inactive gaseous element occurring in air

neptunium (nep-TYOO-nee-um): one of the new, man-made elements

nerve cell: an animal cell which is sensitive to a stimulus and which carries an impulse

nerve fiber: a threadlike band of tissue connecting various parts of the body, carrying impulses

nervous system: the brain, spinal cord, and all the nerves of the body

neutron (NOŌ-tron): a neutral particle in the nucleus of the atom

niacin (NY-uh-sin): a vitamin which prevents pellagra

nitrate: a compound, rich in nitrogen, used as a fertilizer

nitrogen: an inactive, gaseous element making up about 80% of the air

nitrogenous (ny-TROJ-eh-nus) **waste:** body waste that has nitrogen in it

nodule (NOD-yool): a swelling on the root of a plant, generally on the roots of leguminous plants like peas and clover

nuclear reactor: a device for splitting the atom so that it can be made to produce useful energy or valuable radioactive materials

nucleus (NOO-klee-us): a rounded or oval mass of protoplasm, containing chromosomes, present in most plant or animal cells; also the central part of an atom

nutrient (NOO-tree-ent): one of six kinds

of substances used in nourishing and repairing body tissue and thus promoting growth

nylon: a man-made chemical product which may be formed into fibers having great toughness, elasticity, and strength

nymph: an immature stage of certain insects resembling the adult, like the grasshopper

optic nerve: the nerve connecting the eye and the optic centers of the brain

orbit: the course followed by a body in space in its path around another body in space

orbital rocket: a rocket that would have its own path around the earth

ore: a rock from which one or more minerals (substances) can be extracted

organ: any group of tissues performing a special function in a plant or in an animal; for example, stomach, eye, leaf, root

organism: any individual, living animal or plant

oscillator (os-sil-lay-ter): anything that vibrates rapidly, particularly a radio transmitter which sends out radio waves

oscilloscope (os-SIL-oh-skohp): an instrument that makes sound waves appear as waves of light on a screen similar to a small television screen

ovary (OH-ver-ee): an egg-producing organ in a female plant or animal

ovule (OH-vyool): a small, oval-shaped body in an ovary in the flower of a plant; the beginning of a seed

oxidation (oks-ih-DAY-shun): the changing of an element into its oxide by making it combine with oxygen; the burning of fuel, or the slow burning of food which takes place in cells

oxygen: a gaseous element making up about 20% of air

pancreas (PAN-kree-us): a digestive gland, near the beginning of the small intestine, which makes the pancreatic juice and the hormone insulin

pancreatic (pan-kree-AT-ik) **juice:** a powerful mixture of enzymes (made by the pancreas), which can break down all the food nutrients

parallel connection: an arrangement in which all positive poles of a battery, for example, are joined to one conductor, and all negative poles to another conductor, each connection between the two being parallel to the other

partial eclipse: the incomplete hiding or darkening of one body in space by another

pasteurization (pass-ter-ih-ZAY-shun): killing dangerous germs in milk by heating the milk to a temperature of about 145° F. for 20 minutes and then cooling it rapidly

pay load: the contents of an earth satellite or rocket (radio, television, measuring instruments, etc.) useful in gathering information; fuel is not pay load

pellagra (peh-LAY-gruh): a deficiency disease caused by the lack of the vitamin niacin

penicillin (pen-ih-SIL-in): a chemical secreted by *Penicillium*, a mold; discovered by Sir Alexander Fleming, it prevents the growth of certain bacteria

Penicillium (pen-ih-SIL-ee-um): a green or blue mold; secretes penicillin

penumbra (peh-NUM-bruh): the lighter portion of a shadow

pepsin: an enzyme, found in the gastric juice, which helps break down proteins into simpler proteins

perigee (PEHR-ih-jee): the position of an earth satellite at the point in its orbit when it is nearest to the earth

persistence of vision: the ability of the retina to keep an image at least $\frac{1}{16}$ of a second

phases (of the moon): changing views of the moon as seen by an observer on the earth

phosphor: a chemical which gives off visible light when struck by electrons, ultraviolet light, or another invisible radiation

phosphorescence: the capacity of a substance to emit visible light when stimulated by electrons and certain kinds of radiation and to continue to glow after the source of stimulation is removed

photoelectric cell: a cell or vacuum tube used to produce an electric current varying in strength with the light shone on it, as in the sound-producing part of a motion-picture projector

photosynthesis (foh-toh-SIN-thuh-siss): the process by which a green plant makes sugar, in the presence of light, from water and carbon dioxide

physical change: a change in which the original properties of a substance are not destroyed

pig iron: iron that is made in a blast furnace

pistil: the female reproductive organ of a flower, which has in it an ovary with its ovules

pitch: a certain number of vibrations of

sound waves per second. (All musical instruments vibrating 435 times per second produce the sound or pitch of the note A.)

pitchblende: a dark earth ore of uranium

planet: one of the nine bodies circling around the sun; the earth is one

planetoid (PLAN-et-oyd): one of the many small bodies between the orbits of the planets Mars and Jupiter

plasma (PLAZ-muh): the fluid part of the blood which has dissolved food nutrients and such substances as antibodies and red and white blood corpuscles

plastic: a man-made substance capable of being molded, such as cellophane or lucite

plutonium (ploo-TOH-nee-um): a man-made element produced from uranium in an atomic pile

polio (short form for **poliomyelitis**): inflammation of the nerve matter in the spinal cord, sometimes causing paralysis

pollen (POLL-en): powdery grains found in the stamens of seed plants; contain sperm nuclei

pollinate (POLL-ih-nayt): to transfer pollen from the anther to the stigma of the same or a different flower

positive (photographic): a photographic film or print corresponding with the original object in position of lights and shades

potential (po-TEN-sh'l) **energy:** stored energy

power: the rate of doing work, that is, how long it takes to do a certain amount of work

power stroke: the stroke of an engine in which the energy of the burning fuel forces the piston to give power to the engine by turning the crankshaft

powers-of-ten-notation: a convenient way to express measurement of extremely large or extremely small quantities, as 9×10^3 or 9×10^{-3} ($9 \times 1{,}000 = 9{,}000$; $9 \times \frac{1}{1{,}000} = \frac{9}{1{,}000}$)

precipitation (preh-sip-ih-TAY-shun): a term covering all forms of water falling from the sky: hail, snow, rain, and sleet

prevailing wind: a wind which blows almost always from one direction

prominence: a cloud of glowing gas at the surface of the sun and reaching high above it

properties of matter: characteristics, both physical and chemical, that enable us to recognize a substance

protein: a food nutrient containing nitrogen; necessary for the growth of protoplasm

proton (PROH-ton): an atomic particle having a single positive charge and a weight of 1; in the hydrogen atom the proton is the nucleus; in other atoms the nucleus consists of protons and other particles

protoplasm: the semi-solid, jelly-like material of all living cells, including the nucleus, cytoplasm, and the membrane of cells

protozoa (proh-toh-ZOH-uh): single-celled animals, such as paramecium or ameba, which are usually found in ponds or stagnant water

psychrometer (sy-KROM-uh-ter): an instrument used to determine the percentage of relative humidity

ptomaine (TOH-mayn): poisonous substance formed by the action of certain bacteria

pulley: a wheel with a grooved rim, used with a rope or chain to change the direction of a pulling force; a simple machine

pulse: a short, strong electromagnetic signal that issues from radar equipment

pupa (PYOO-puh): the inactive stage in the development of an insect passing through egg, larva, pupa, and then adult stages

pupil: the opening in the iris of the eye which changes in size with different amounts of light

pus: yellowish-white matter made of dead tissue, white blood cells, bacteria, and so on, produced as by an abscess or boil

quarantine (KWAHR-en-teen): isolation of any organism which carries a contagious disease

quinine (KWY-nyne): a drug used in preventing and treating malaria

radar: abbreviation for *ra*dio *d*etection *a*nd *r*anging, the device which is used for the detection of objects by radio waves

radiant heating: a heating system in which hot water or steam pipes set in floors or walls send out heat into rooms

radiation: the process by which energy is transferred in space; for instance, in the form of electromagnetic waves; also radiant energy

radioactivity: the property, possessed by certain elements, of naturally sending forth radiant energy through breaking up of atoms; also characteristic of substances made radioactive in an atomic pile

radiosonde (RAY-dee-oh-sond): a radio transmitter attached to a balloon and sent aloft

by observers seeking information about weather conditions in the upper atmosphere

receiver (radio): an apparatus (like your radio) which receives signals sent out by a transmitter and which demodulates (changes) these signals so that they may be heard as speech, music, or code signals

recessive trait: an inherited characteristic which will not develop in a plant or an animal if the plant or animal contains any genes for the dominant trait (which hides the recessive)

rectum: the lowest part of the intestine, from which undigested food leaves the body

reflected light: light that is cast back or returned by an object

reflex: an inborn automatic act

refrigerant: a liquid, such as ammonia, which evaporates easily and therefore is useful in the cooling coils of a refrigerator

relative humidity: the ratio of the amount of water vapor present in the air to the greatest amount which would be possible at a given temperature

relay: an electric device used to open or close circuits by remote control

resistance: the weight to be lifted or moved by a simple machine (such as a lever or pulley) when enough force is applied; a device that slows the flow of electrons in an electrical circuit

resonance: an object is said to be in resonance with another when both vibrate with the same frequency

response: the reaction of a plant or animal to a stimulus

retina (RET-ih-nuh): the inner lining of the eye, containing light-sensitive cells

reverse-rocket approach: the use of rocket motors to allow a space ship to come down tail first, to a more or less gentle landing

revolution: a single cycle of a body in space about another body in space; for example, the earth's yearly revolution about the sun

riboflavin (ry-boh-FLAY-vin): vitamin B_2 found in meats, dairy products, and green vegetables

rodent: an animal belonging to the order of gnawing mammals, such as rats and squirrels

Roentgen rays: the same as X rays

root hair: a root cell from which a hairlike extension grows; it increases absorption of water and minerals

rotating crops: a farming method in which different plants are sown in the same soil in succeeding years; for example, during a three-year period corn, oats, and clover are rotated in the same field

rotation: the motion of any object about a central axis, such as the rotation of the earth in 24 hours

rudder: a flat piece of fabric-covered wood or a piece of metal hinged to the vertical fin of an airplane to control its direction to the right or left

rust: a fungus, related to the smuts, different forms of which cause plant diseases such as wheat rust; also the result of oxidation, such as the rusting of iron

saliva: a fluid secreted by glands discharging into the mouth

salivate (SAL-iv-ate): to produce a large amount of saliva

sanctuary (wildlife): a haven for wild animals, where hunting is prohibited or regulated

satellite: a small body which revolves around a planet; a moon; also a man-made body hurled into space to revolve around the earth or other body

saturated (SACH-er-ayt-id) **solution:** a solution containing all the dissolved material it can hold (under given conditions)

screw: one of the simple machines

scurvy: a disease due to a lack of vitamin C; it causes bleeding under the skin and softening of the gums of the mouth

season: a period of the year marked by certain characteristic conditions of the weather and plant growth; for example, spring

seismograph (SYZE-muh-graf): a sensitive instrument used to record vibrations of the earth's crust and to detect earthquakes

sense organ: a part of the body which senses, or receives, stimuli coming from the surroundings

series connection: an arrangement in which a positive pole of a battery, for example, is connected by wire to a negative pole, all connections being in one circuit. *See* parallel connection

serum albumin (SEER-'m · al-BYOO-min): a substance making up a large part of blood plasma, used to treat shock and severe burns

sexual reproduction: production of a new organism from the union of two cells, sperm and egg

shock wave: the mass of piled-up air that can rip the wings from an ordinary airplane attempting to fly faster than the speed of sound (760 miles an hour); also used to describe the wave after the blast of an atomic bomb

short circuit: a condition resulting when two bare wires carrying electricity touch each other

simple machine: a machine, such as a lever, inclined plane, screw, wedge, wheel and axle, or pulley, that aids in doing work

single-stage rocket: a rocket that makes a flight in one step; it is a single rocket

sinus (SY-nus): a cavity in the bones of the skull connected with the nostrils and containing air

sky wave: an electric signal reflected from the thin, upper atmosphere called the ionosphere or "radio roof"

slow oxidation: the slow burning of a substance, or the burning of food which takes place in cells; rusting of iron

soft coal: bituminous coal that yields illuminating gas, coal tar, and coke upon being heated without access to air

soft water: water that is relatively free from mineral salts

solar (SOH-ler) **system:** the sun with the group of bodies in space which, held by its attraction, revolve around it

solid: a compact body having size, shape, and weight

solstice (SOL-stiss): the period when the sun appears to remain for a few days at noon at its highest point (about June 21) and at its lowest point (about December 21) as seen from the Northern Hemisphere

soluble: capable of being dissolved

solution: a liquid containing a dissolved substance (solute)

sonar (SOH-nahr): the submarine detection apparatus that can locate objects by using sound waves which bounce back from the object

sound barrier: the shock waves caused by air particles piling up against a plane flying at the speed of sound

sounder: the portion of a telegraph receiver which is struck by the moving armature and thus makes the clicking sounds of dots and dashes

species: a distinct kind or sort of animal or plant

spectrum: an arrangement of rays of light or other forms of radiant energy (such as radio waves, infrared waves, ultraviolet rays) according to the wave length

sperm: a male sex cell which unites with an egg cell during fertilization

spinal cord: the thick cord of nerve tissue extending along, and protected by, the backbone

spiracles (SPY-ruh-c'ls): breathing openings in the bodies of insects

spirillum (spy-RIL-lum) (pl., spirilla): one type of bacterium, so named because of its spiral or comma shape

spleen: a small organ near the stomach in which some of the red blood cells are stored

spontaneous combustion: the bursting into flame of a substance due to the accumulated heat of slow oxidation

spore: a thick-walled plant cell (for instance, a bacterial spore) which can withstand such unfavorable conditions as lack of food, dryness, and extreme cold

spring tide: the highest of high tides and the lowest of low tides. *See* neap tides

stamen (STAY-men): the male reproductive organ of a flower, which produces pollen grains

standard time: in the United States: Eastern, Central, Mountain, and Pacific standard times, corresponding to the time of the 75th, 90th, 105th, and 120th meridians west of Greenwich

starch: a carbohydrate that is insoluble and when digested produces glucose

static (STAT-IK) **electricity:** charges of electricity produced by friction

steam engine: an engine driven by the energy of steam

steel: iron to which enough carbon, manganese, silicon, etc., have been added to give it hardness and strength

stigma: in plants, the sticky top portion of the pistil which receives the pollen

stimulus (STIM-yoo-lus) (pl., stimuli): anything that causes a temporary increase of activity in a living body or any of its parts

stomach poison: a poison that kills insects if taken into their stomach

stomate (STOH-mayt): tiny openings in leaves which allow gases to pass and water to leave. *See* guard cell

storage battery: a battery which stores electricity on plates of different chemical composition; it is charged by sending in electric current which causes a chemical change

stored energy: energy stored up in an object; called potential energy

stratosphere (STRAT-uh-sfeer): the middle region of the atmosphere between the troposphere and the ionosphere

stratus (STRAY-tus) **cloud:** a cloud that extends horizontally over a large area and is at a low altitude

streptomycin (strep-toh-MY-sin): a chemical, produced by certain soil bacteria, which slows down or stops the growth of other bacteria; useful against tuberculosis

strip cropping: a farming method in which several types of plants are sown in alternate strips

strip mining: mining done by scraping away the surface earth that covers the bed of ore, etc., to be mined

suspension: an insoluble solid suspended in a liquid; for example, soil in water

sweat gland: a gland in the skin which excretes a fluid made of water, salts, and urea onto the skin surface by means of ducts

tagged atoms: radioactive atoms that may be detected by a Geiger counter, usually as they move through the tissues of plants and animals

tendon: tough tissue binding muscles to bones

theodolite (thee-OD-oh-lite): an optical instrument which can be used to measure the height and speed of clouds or balloons

theory: a scientifically acceptable principle offered in explanation of observed facts

thermograph (THER-moh-graf): a device used to make an automatic and continuous record of temperature changes

thermometer: an instrument for measuring the temperature at a particular moment

thermostat: a device on a heating system which automatically controls temperature (as by regulating a damper, flow of fuel, etc.)

thiamine (THY-uh-min): a vitamin of the B complex, also called vitamin B_1; it prevents beriberi

thrust: the forward motion given to an airplane by its propeller or jet engine

thunder: the sound following a flash of lightning due to the sudden expansion of air in the path of the discharge

tissue: a group of similar cells performing the same function; for example, muscle or nerve tissue

topsoil: the upper fertile layer of soil, containing humus, which is necessary to plant life

tornado: one of the most violent of windstorms, noted for its funnel-shaped clouds, high-speed winds, and great destructiveness over a short path and a small area

total eclipse: the complete hiding of one heavenly body by another or by the umbra of the shadow cast by another

toxin: a poison formed by germs, as in diphtheria

trade winds: winds which could be depended upon to blow in a definite direction and so were used by cargo ships

trait: a distinguishing quality of a person or thing

transformation of energy: the change of energy from one form to another, as when a battery changes chemical energy into electrical energy

transformer: a device for transforming high voltage to low voltage, or low voltage to high voltage

transistor: an electronic device that controls the flow of electrons

transmission (automobile): a device which transfers the motion of the automobile engine into several speeds of forward motion and one of reverse motion

transmitter: the part of a device used in communication which sends out the signals intended for a distant receiver

trichina: a parasitic roundworm found in the flesh of animals, causing trichinosis

trichinosis (trik-ih-NOH-siss): a disease caused by a parasitic roundworm in the muscles of animals, usually those of hogs

tritium (TRIT-ee-um): a form of hydrogen whose atoms are three times heavier than atoms of ordinary hydrogen

tropical hurricane: a violent storm originating in the tropics, often called a cyclone or typhoon

troposphere (TROP-uh-sfeer): the lowest portion of the atmosphere, the part in which we live

turbine (TER-bin): a rotary engine moved by steam or water

ultrasonic (ul-truh-SON-ik) **sound:** refers to high-pitched sound above the range of human hearing

ultraviolet ray: an invisible ray which lies beyond the violet end of the spectrum; such a ray is given off by very hot bodies,

by certain kinds of lamps, and by the sun in sunlight

umbra (UM-bruh): the darker portion of a shadow

uranium: a heavy, white, radioactive element occurring in an ore called pitchblende. *See* pitchblende

urea (yoo-REE-uh): a solid crystalline compound containing nitrogen; the chief part of urine

vaccinate: to inoculate with dead or weakened germs, causing a light attack of a disease in order to prevent a serious attack of the same disease, as in smallpox

vaccine: any substance, usually containing dead or weakened bacteria, prepared for introduction into the body (usually by breaking the skin) to cause an immunity to the disease

vein: one of the tubular branching vessels that carry blood back to the heart; a duct in plant leaves

velocity: the rate of time in which a distance is covered in a specific direction

velocity of escape: the speed and direction necessary for an earth satellite to overcome the pull of gravity

ventricle: one of the muscular chambers of the heart which pump blood to parts of the body

vertebrate: an animal having a backbone

vibration: movement due to the effect of waves on a membrane; caused by sound waves, among others

villus (VIL-lus) (pl., villi): one of the many tiny tubelike structures on the inside wall of the small intestine which serve to absorb food

virus (VY-rus): a tiny living particle (not made up of cells) which causes such diseases as smallpox; thought to be a large protein molecule

vitamin (VY-tuh-min): a chemical found in foods and needed in small quantities for special body functioning; lack of a particular vitamin causes a deficiency disease

vitamin A: a chemical found in milk, eggs, and green vegetables; helps to prevent the common cold and also helps to improve seeing, especially at night

vitamin B_1: a substance (thiamine) found in whole grains and vegetables; prevents beriberi

vitamin C (ascorbic acid): the vitamin which prevents scurvy and which keeps the skin and teeth healthy

vitamin D: a vitamin found in cod and halibut liver oils; called the "sunshine vitamin"; helps bone growth

vitamin K: a vitamin which helps the blood to clot easily

volcano: an opening in the earth's crust from which molten rock, steam, etc., are poured or thrown forth

volt: a unit for measuring electric pressure

voltaic cell: an arrangement for generating electricity by the action of a chemical upon two unlike metals

voltmeter: a meter for measuring pressure (voltage) of an electric current

warm front: the boundary between a mass of advancing warm air and a retreating mass of relatively cooler air

water cycle: the continuous changes of water — evaporating from the surface of the earth (oceans, lakes, streams, etc.) into water vapor, eventually forming clouds and condensing as rain, then flowing back into lakes, streams, and oceans

watershed: the region or area drained by a river or lake

water table: the level below which the soil is saturated with water

watt: the unit for measuring electric power

wave length: the distance from any point on a wave to the corresponding point on the next wave

weathering: the gradual destruction of material exposed to the weather; wind, moisture, sunlight, heat, and cold are the chief causes of weathering

wedge: a piece of wood or metal, tapered to a thin edge and used to split or raise heavy objects; a simple machine

wheel and axle: a device consisting of a grooved wheel with an attached axle, used for lifting heavy objects; a simple machine

white blood cells: the kind of blood cell that helps destroy bacteria and other foreign particles that enter the body

work: the product of a force times the distance the force moves a body, usually measured in foot-pounds; work is done whenever a body is moved, or its motion stopped, by a force

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Index of Experiments and Activities

* At the end of each chapter, a section bearing this title offers suggestions for investigating careers. These follow the sections entitled "Going Further" in this index.

Acknowledgments

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The authors also wish to acknowledge their gratitude to those whose inspiration in making possible the publication of SCIENCE FOR BETTER LIVING: Complete Course *has carried over to* YOU AND SCIENCE: Miss Edna Craig, Newburgh High School, Newburgh, New York; Dr. Irene Jaworski, Forest Hills High School, Forest Hills, New York; Dr. C. W. Mattison, Forestry Education Consultant, U.S. Forest Service; Miss Evelyn Morholt, Forest Hills High School, Forest Hills, New York; Mr. Hyman Ruchlis, Bushwick High School, Brooklyn, New York; and Miss Ella Thea Smith, formerly of the Salem, Ohio, High School.

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FRONT COVER *U.S. Air Force three-stage space rocket ready for take-off.*

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